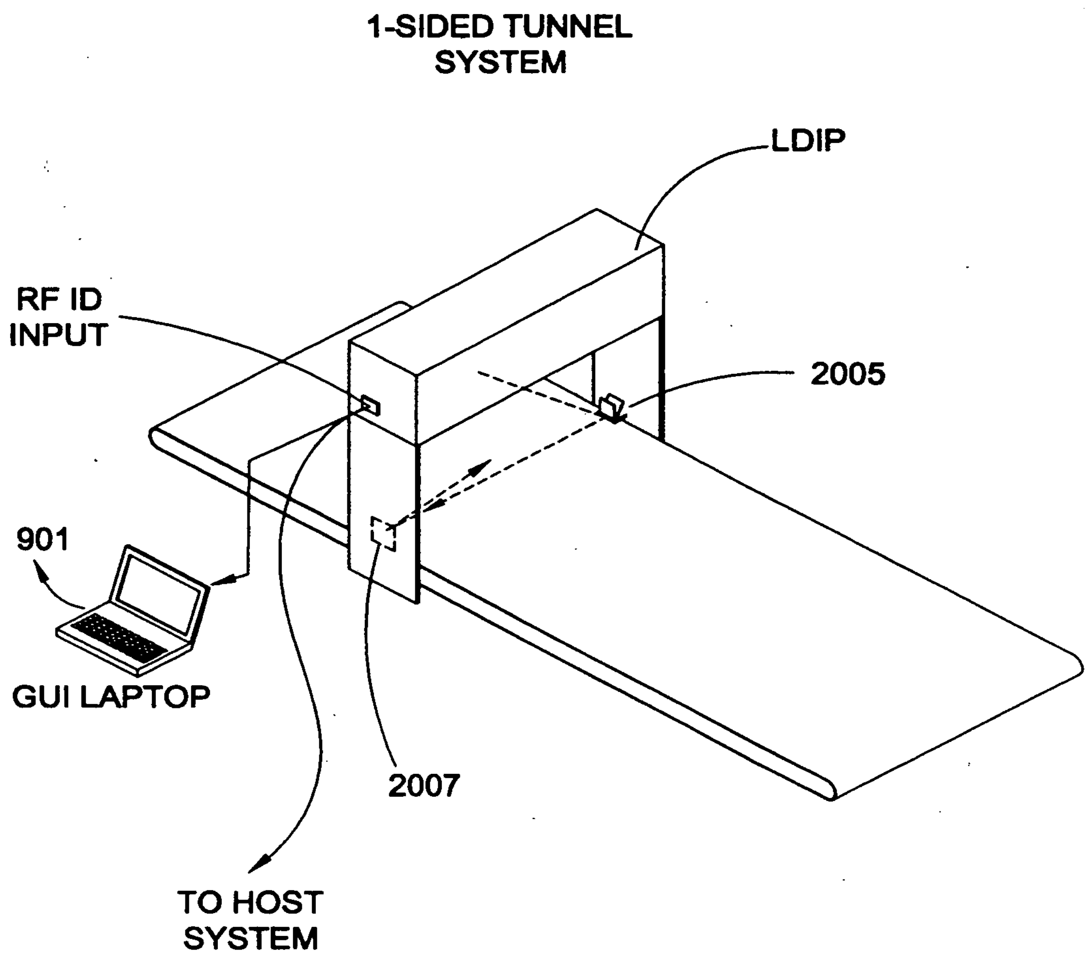

1-SIDED TUNNEL
SYSTEM
LDIP
RF ID
INPUT
2005
901
GUI LAPTOP
2007
TO HOST
SYSTEM

FIG. 1A

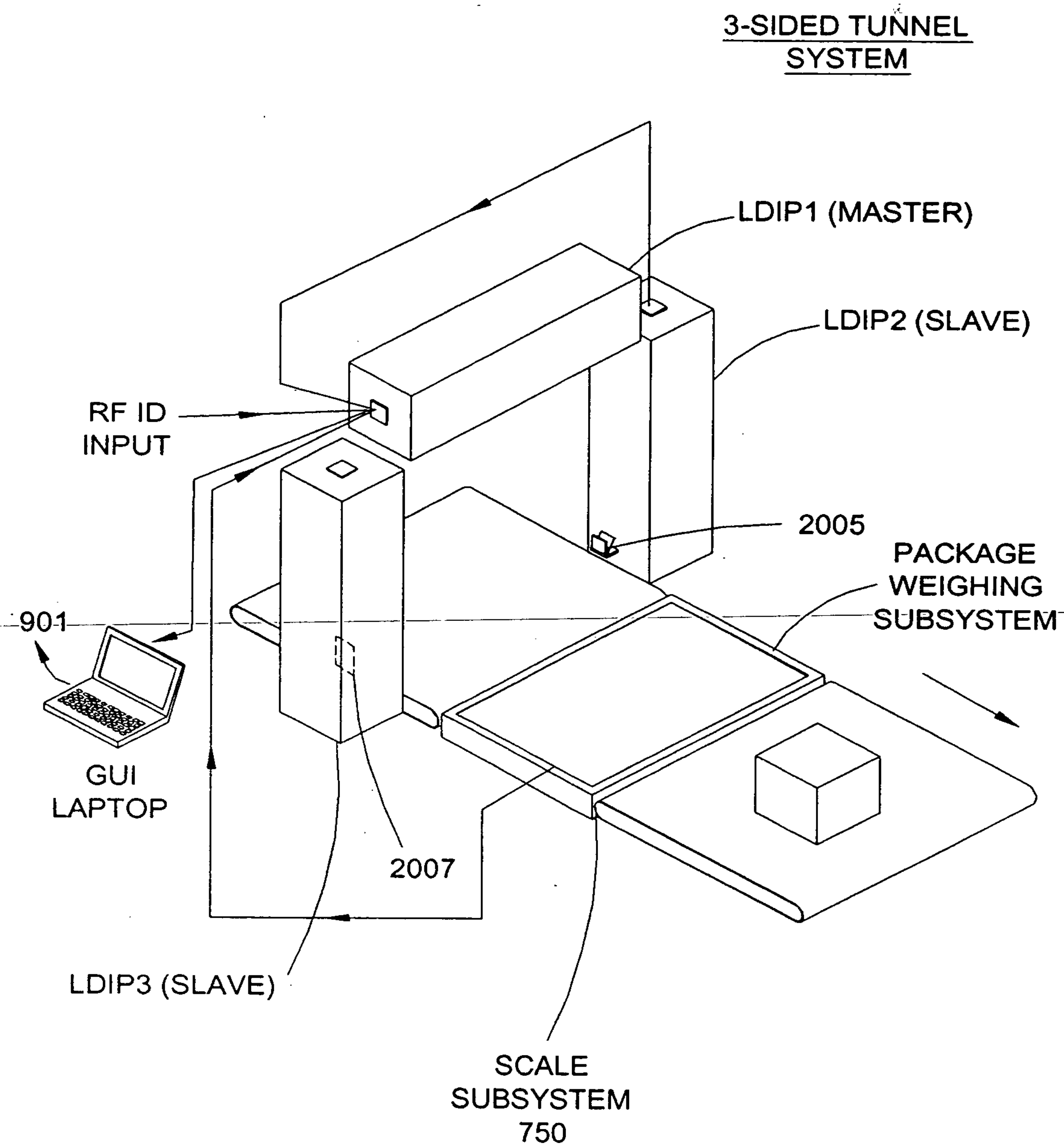

3-SIDED TUNNEL SYSTEM
LDIP1 (MASTER)
LDIP2 (SLAVE)
RF ID INPUT
2005
PACKAGE WEIGHING SUBSYSTEM
901
GUI LAPTOP
2007
LDIP3 (SLAVE)
SCALE SUBSYSTEM 750

FIG. 1B

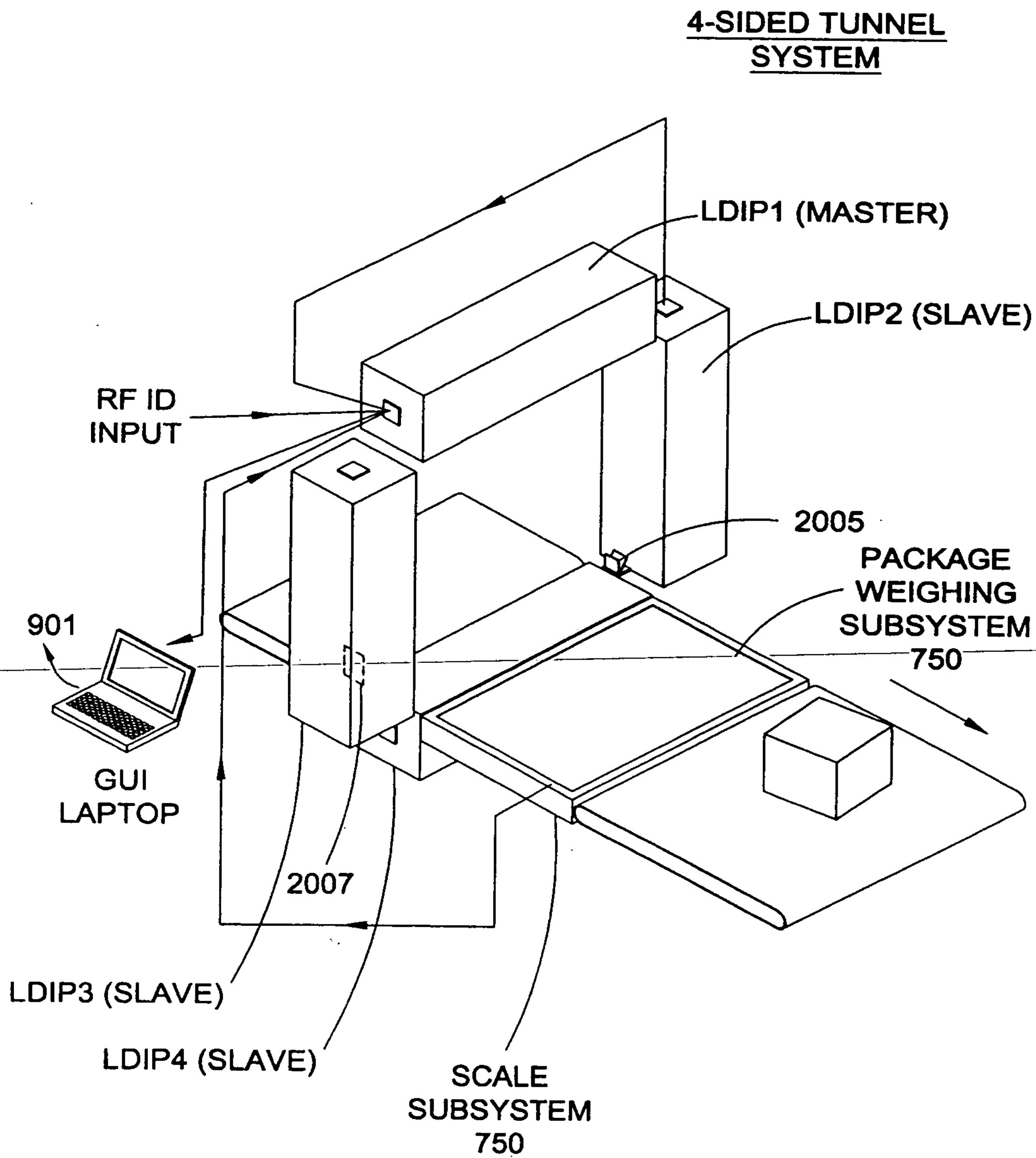

4-SIDED TUNNEL SYSTEM
LDIP1 (MASTER)
LDIP2 (SLAVE)
RF ID INPUT
2005
PACKAGE WEIGHING SUBSYSTEM 750
901
GUI LAPTOP
2007
LDIP3 (SLAVE)
LDIP4 (SLAVE)
SCALE SUBSYSTEM 750

FIG. 1C

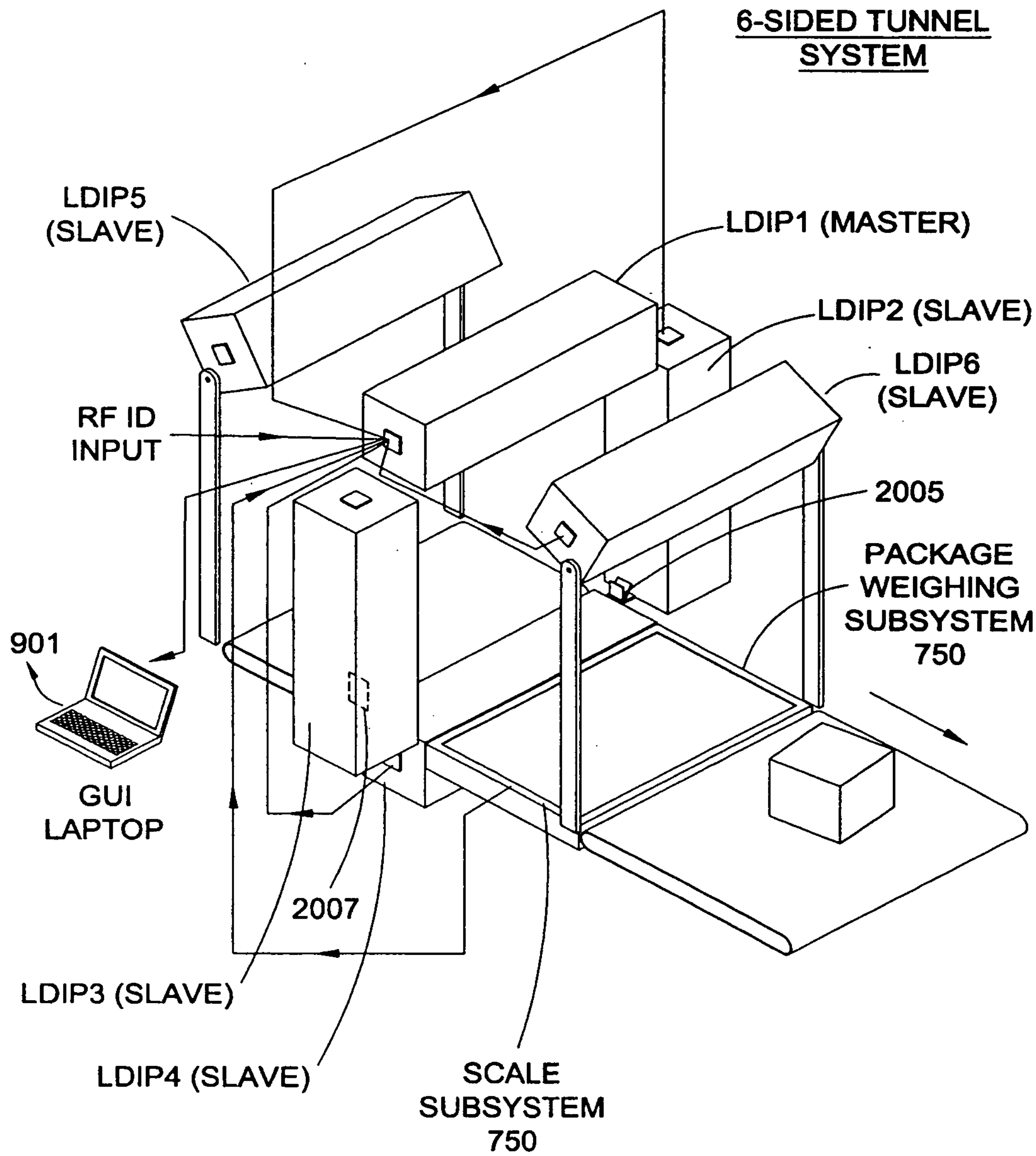

6-SIDED TUNNEL SYSTEM
LDIP5 (SLAVE)
LDIP1 (MASTER)
LDIP2 (SLAVE)
LDIP6 (SLAVE)
RF ID INPUT
2005
PACKAGE WEIGHING SUBSYSTEM 750
901
GUI LAPTOP
2007
LDIP3 (SLAVE)
LDIP4 (SLAVE)
SCALE SUBSYSTEM 750

FIG. 1D

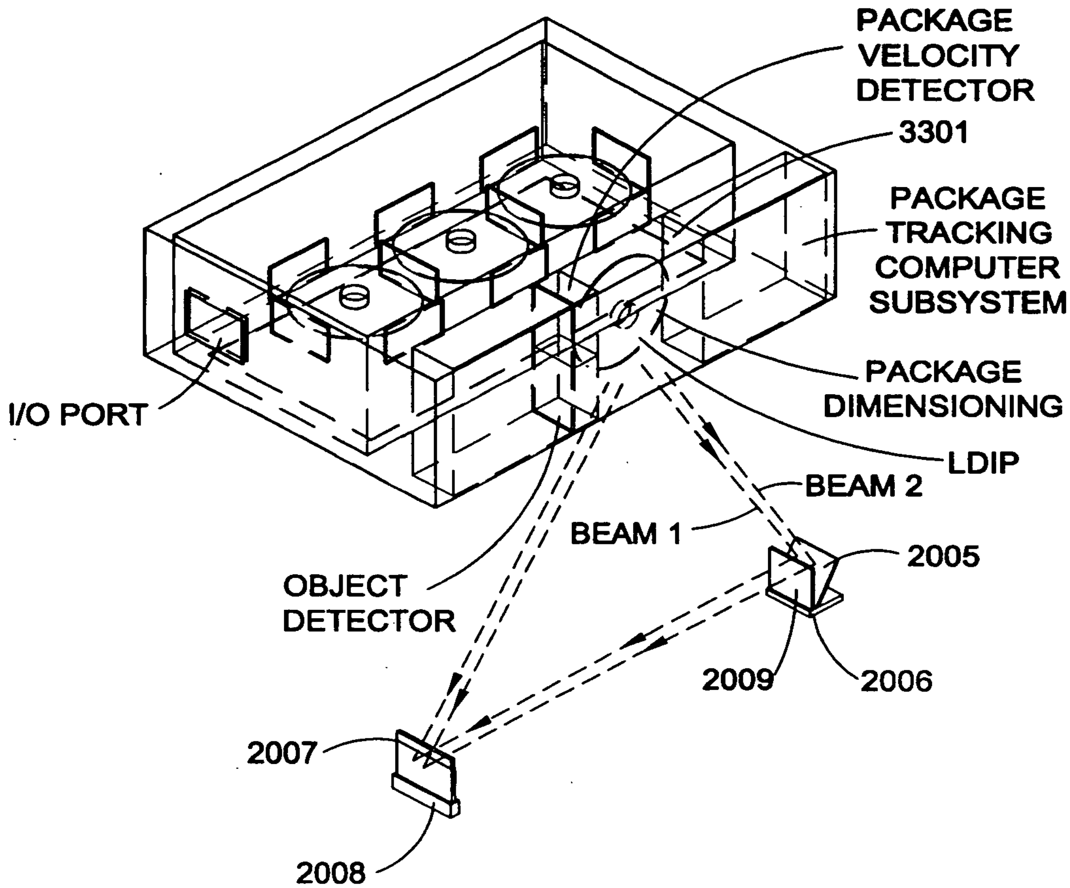

PACKAGE VELOCITY DETECTOR
3301
PACKAGE TRACKING COMPUTER SUBSYSTEM
PACKAGE DIMENSIONING
LDIP
BEAM 2
BEAM 1
2005
I/O PORT
OBJECT DETECTOR
2009
2006
2007
2008

FIG. 2A

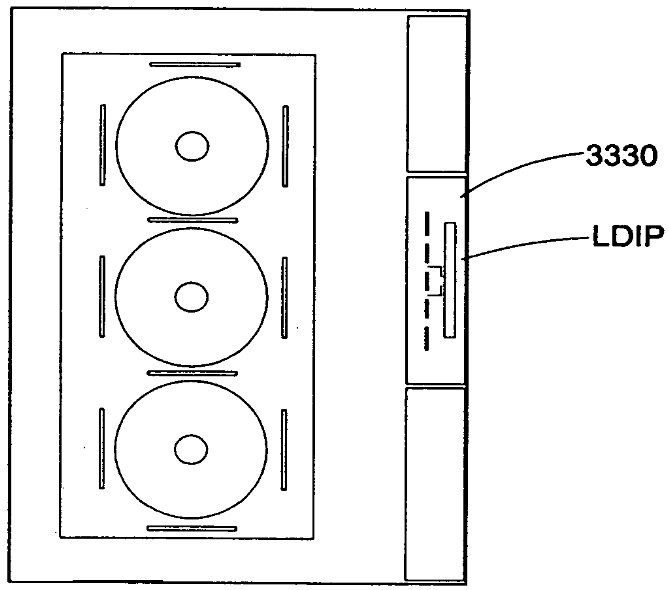
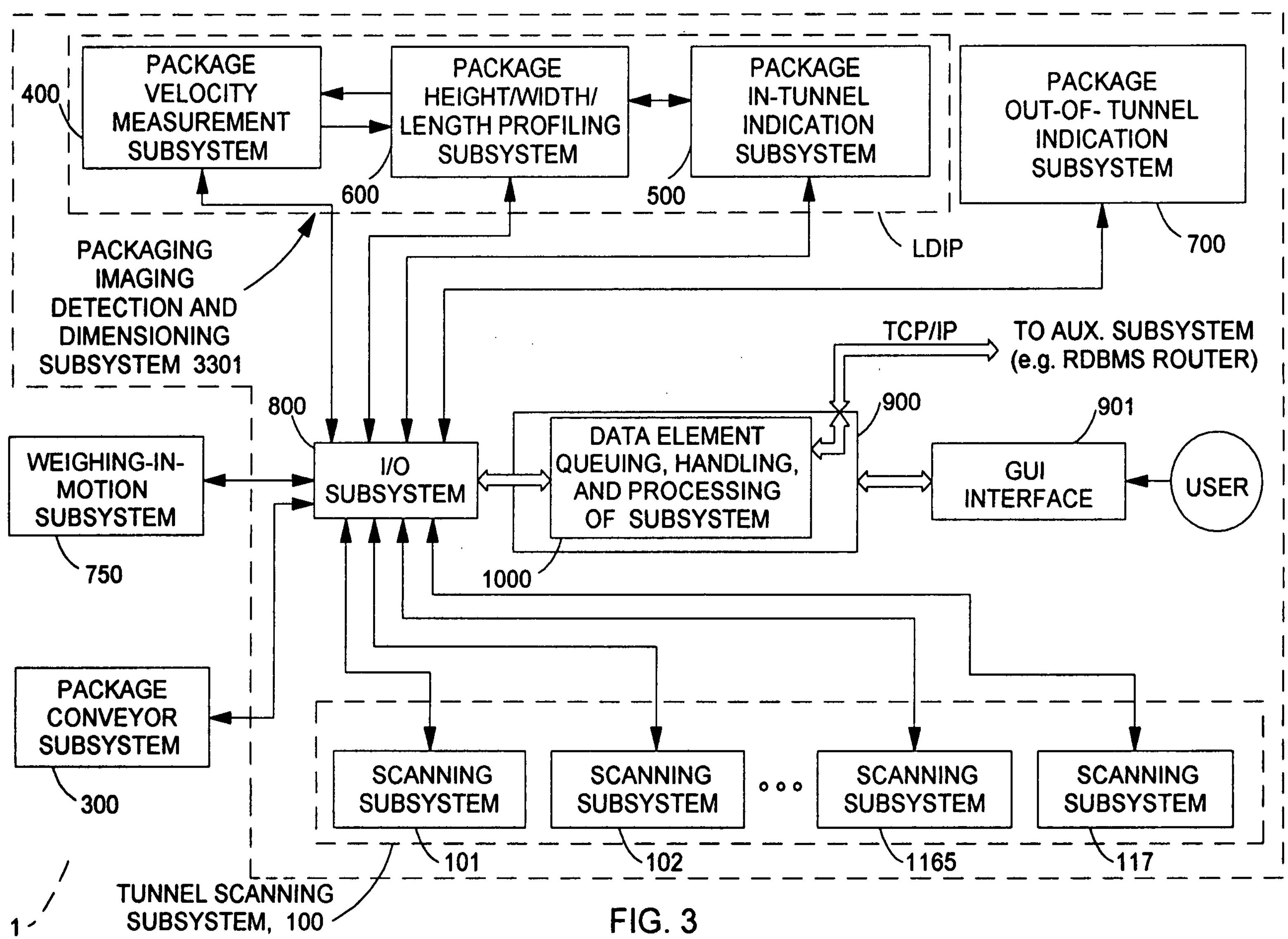


FIG. 2B



PACKAGE VELOCITY MEASUREMENT SUBSYSTEM
400
PACKAGE HEIGHT/WIDTH/ LENGTH PROFILING SUBSYSTEM
600
PACKAGE IN-TUNNEL INDICATION SUBSYSTEM
500
LDIP
PACKAGE OUT-OF- TUNNEL INDICATION SUBSYSTEM
700
PACKAGING IMAGING DETECTION AND DIMENSIONING SUBSYSTEM 3301
TCP/IP
TO AUX. SUBSYSTEM (e.g. RDBMS ROUTER)
800
I/O SUBSYSTEM
DATA ELEMENT QUEUING, HANDLING, AND PROCESSING OF SUBSYSTEM
900
1000
GUI INTERFACE
901
USER
WEIGHING-IN-MOTION SUBSYSTEM
750
PACKAGE CONVEYOR SUBSYSTEM
300
SCANNING SUBSYSTEM
101
SCANNING SUBSYSTEM
102
SCANNING SUBSYSTEM
1165
SCANNING SUBSYSTEM
117
TUNNEL SCANNING SUBSYSTEM, 100
1

FIG. 3

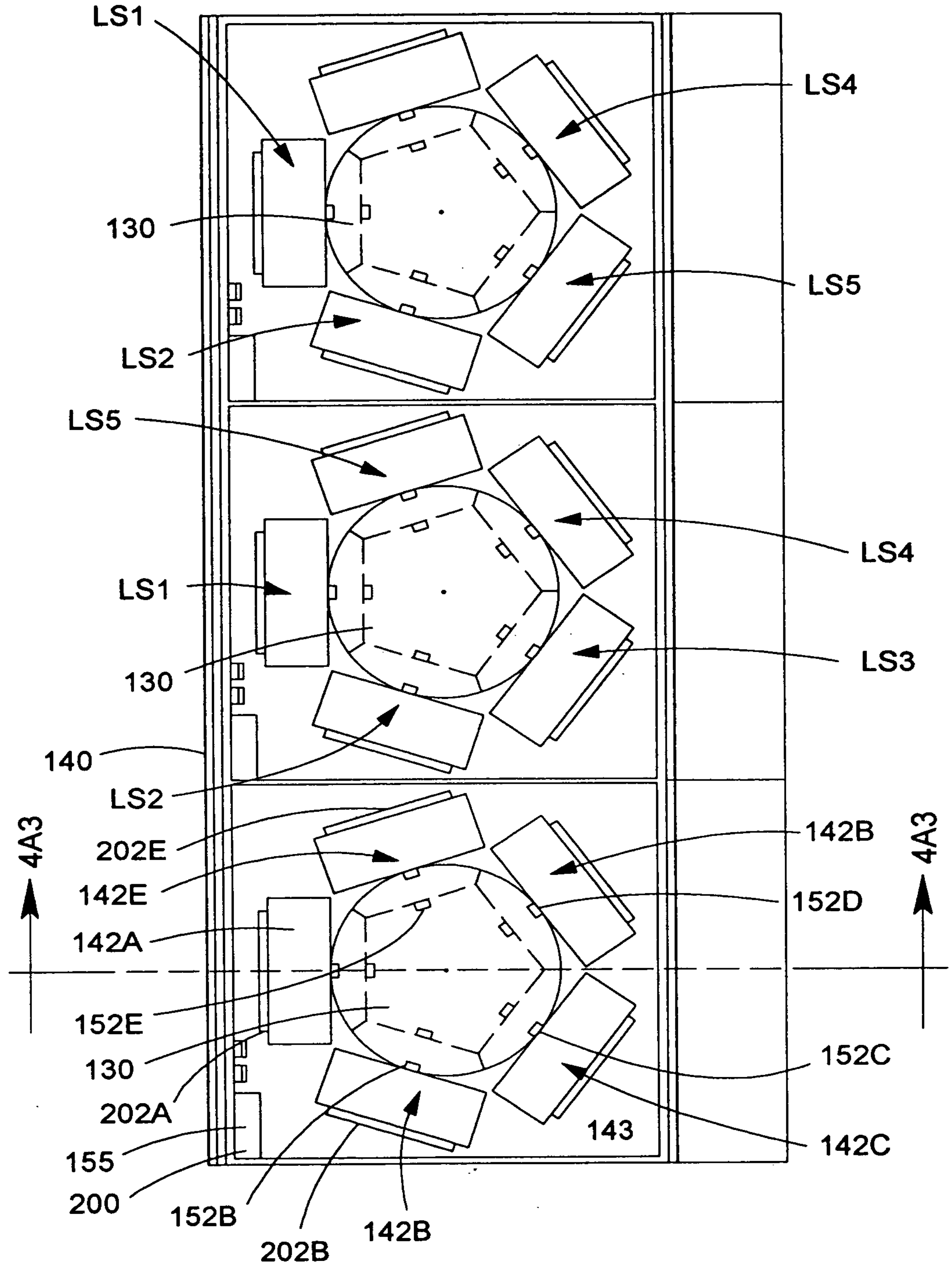

LS1
LS4
130
LS5
LS2
LS5
LS4
LS1
130
LS3
140
LS2
202E
142B
4A3
4A3
142E
152D
142A
152E
130
152C
202A
143
155
142C
200
152B
202B
142B

FIG. 4A1

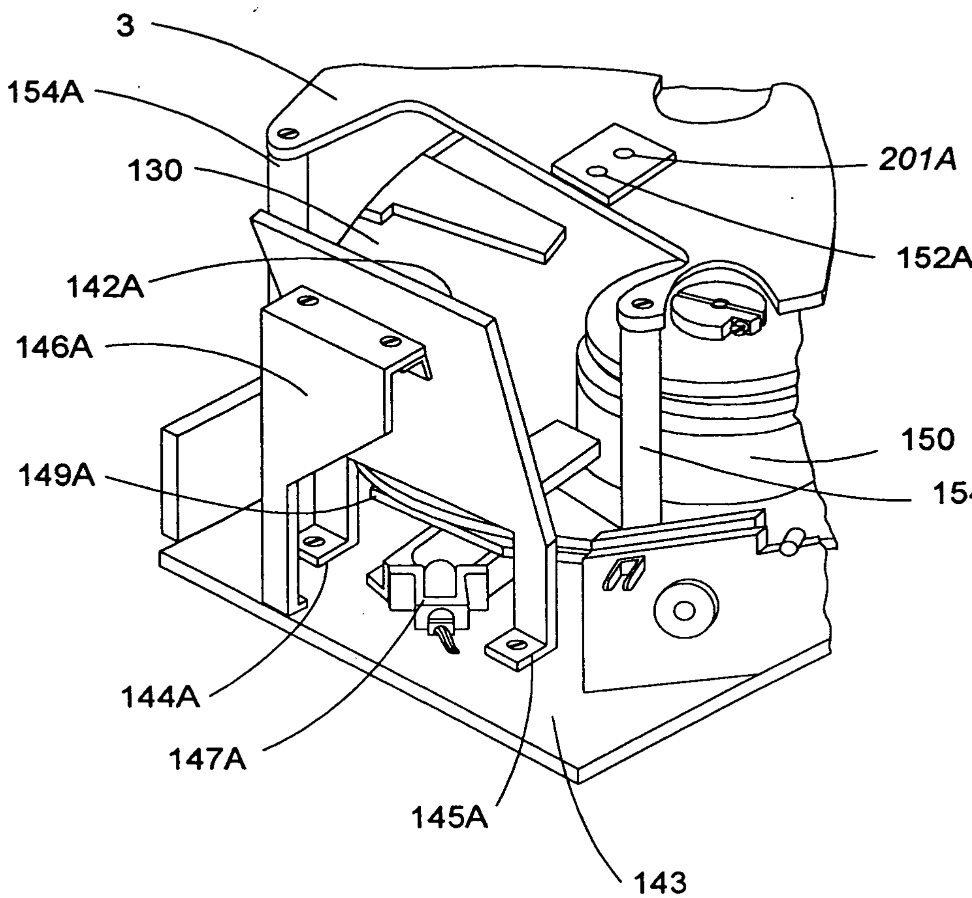
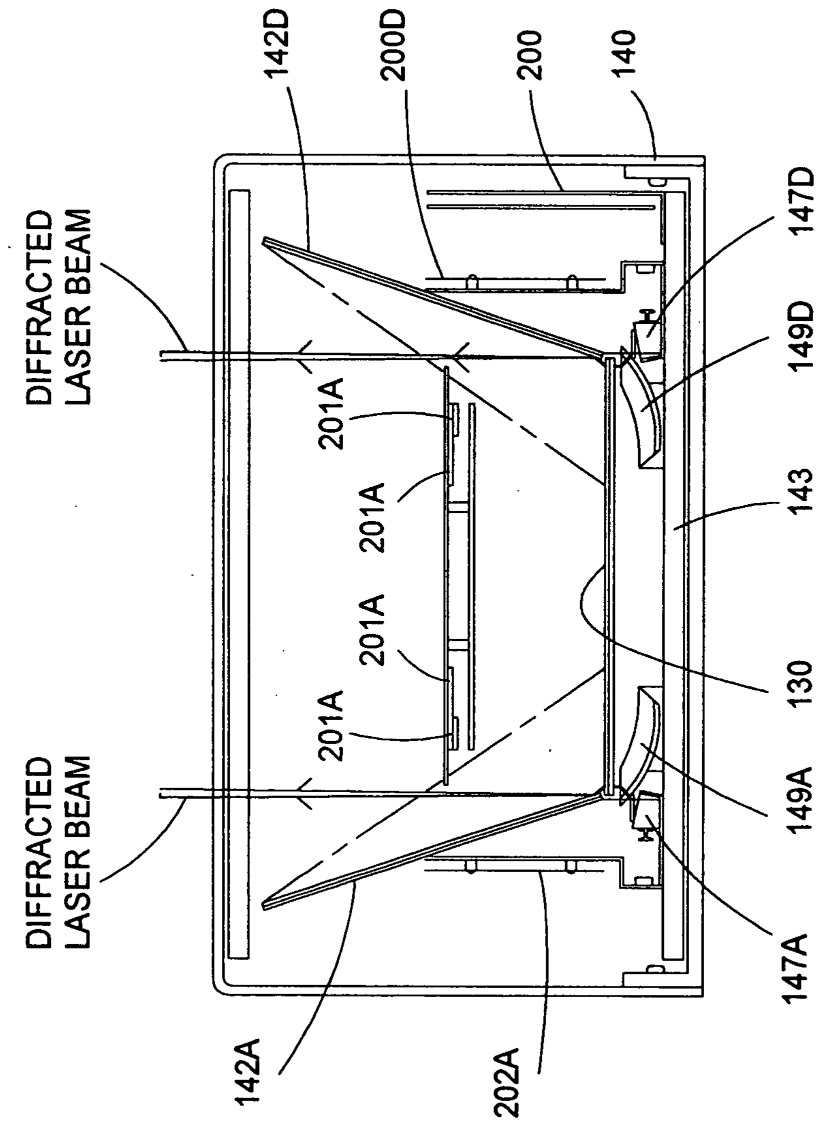


FIG. 4A2



DIFFRACTED LASER BEAM
DIFFRACTED LASER BEAM
142D
200D
200
140
147D
149D
143
130
149A
147A
201A
201A
201A
201A
142A
202A

FIG. 4A3

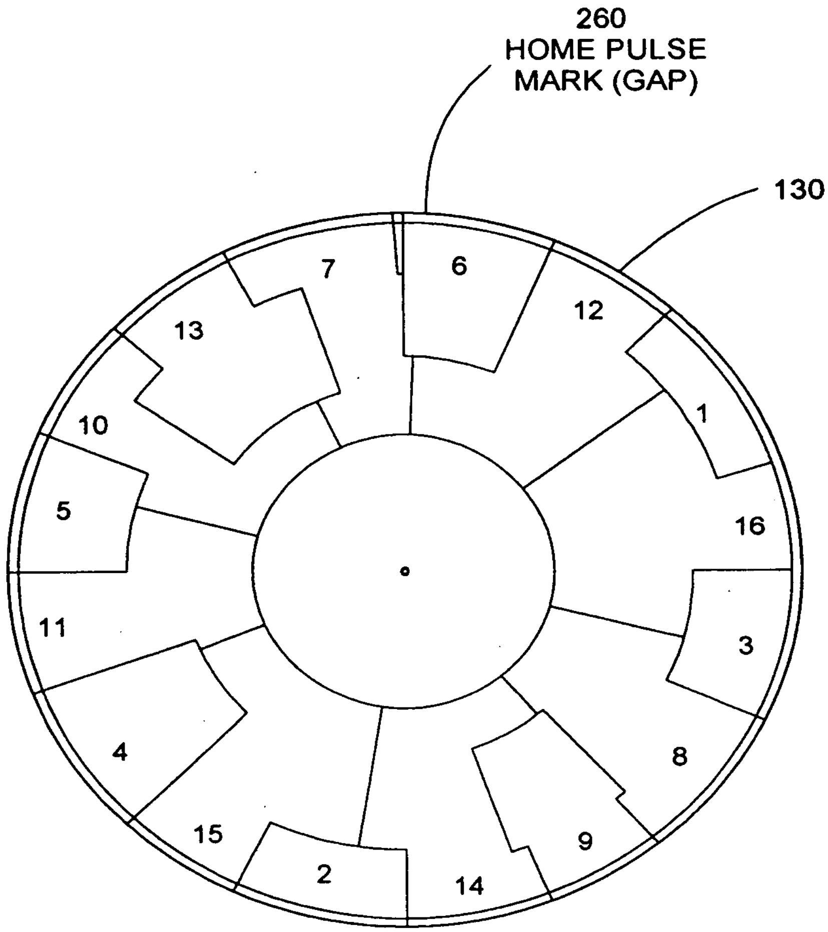


FIG. 4A4

FACET	DIFFRACTION FOCAL LENGTH (INCHES)	GEOMETRICAL FOCAL LENGTH (INCHES)	ANGLE A (DEGREE)	ANGLE B (DEGREE)	ANGLE OF DIFFRACTION (DEGREES)	ANGLE OF BEAM FROM VERTICAL (DEGREES)	SCAN ANGLE (DEGREES)	SCAN MULT. FACTOR (m)	ROTATION ANGLE (DEGREES)
1	49.57	49.76	45.9	61.06	28.94	-3.06	29.61	1.26	23.51
2	49.54	49.73	45.9	55.62	34.38	2.38	29.62	1.34	22.10
3	49.96	50.16	45.9	50.23	39.77	7.77	29.39	1.41	20.77
4	50.81	51.01	45.9	44.97	45.03	13.03	28.92	1.48	19.52
5	49.57	49.76	45.9	61.06	28.94	-3.06	29.61	1.26	23.51
6	49.54	49.73	45.9	55.62	34.38	2.38	29.62	1.34	22.10
7	49.96	50.16	45.9	50.23	39.77	7.77	29.39	1.41	20.77
8	50.81	51.01	45.9	44.97	45.03	13.03	28.92	1.48	19.52
9	59.06	59.38	45.9	60.56	29.44	-2.56	25.01	1.25	55.73
10	59.04	59.36	45.9	56.00	34.00	2.00	25.02	1.32	55.73
11	59.39	59.72	45.9	51.47	38.53	6.53	24.88	1.39	55.73
12	60.10	60.44	45.9	47.01	42.99	10.99	24.59	1.44	55.73
13	59.06	59.38	45.9	60.56	29.44	-2.56	25.01	1.25	55.89
14	59.04	59.36	45.9	56.00	34.00	2.00	25.02	1.32	55.89
15	59.39	59.72	45.9	51.47	38.53	6.53	24.88	1.39	55.89
16	60.10	60.44	45.9	47.01	42.99	10.99	24.59	1.44	55.89

FIG. 4A5

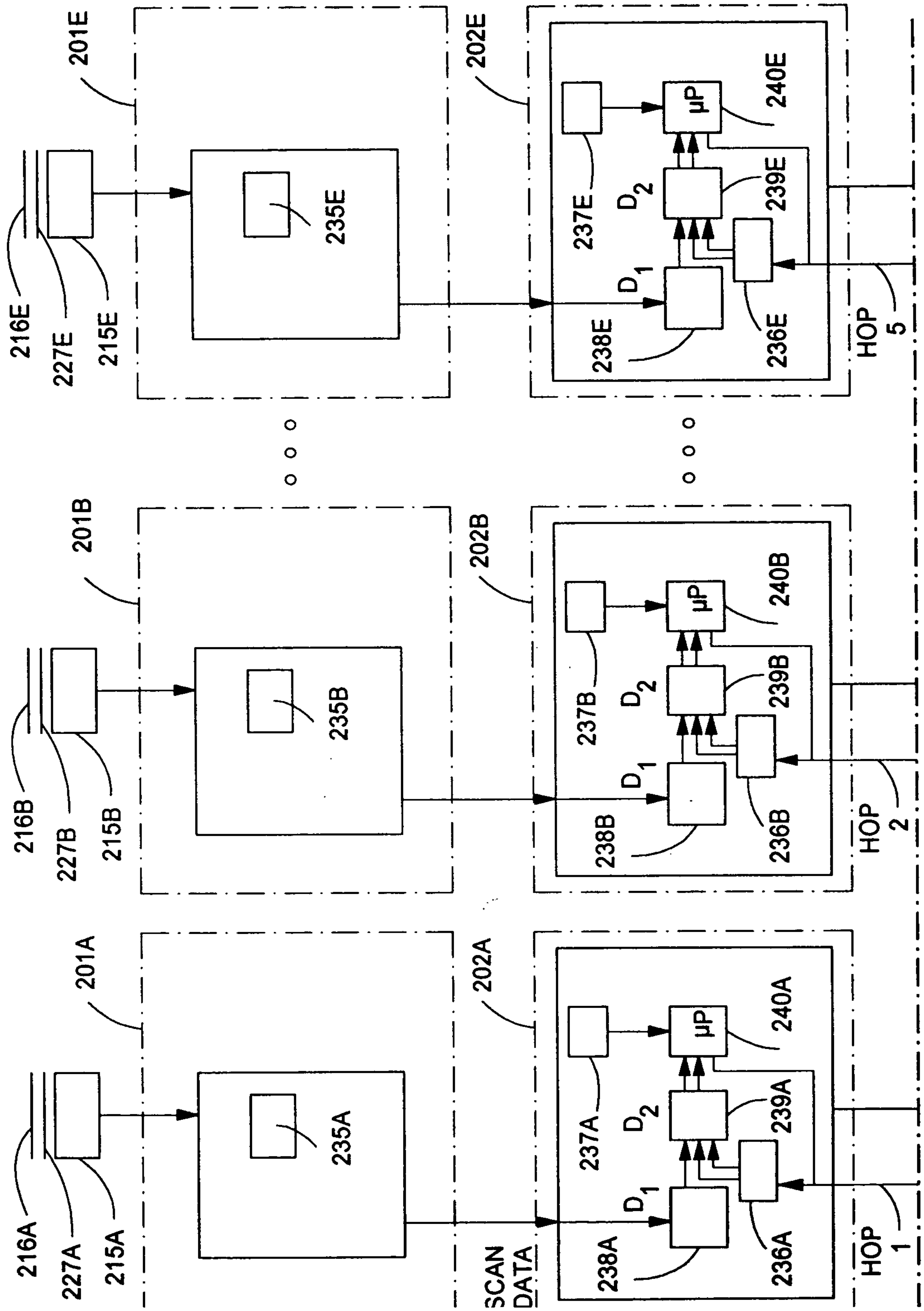

216A
227A
215A
201A
235A
202A
SCAN DATA
238A
D_1
236A
237A
D_2
239A
μP
240A
HOP 1
216B
227B
215B
201B
235B
202B
238B
D_1
236B
237B
D_2
239B
μP
240B
HOP 2
216E
227E
215E
201E
235E
202E
238E
D_1
236E
237E
D_2
239E
μP
240E
HOP 5

FIG. 5A

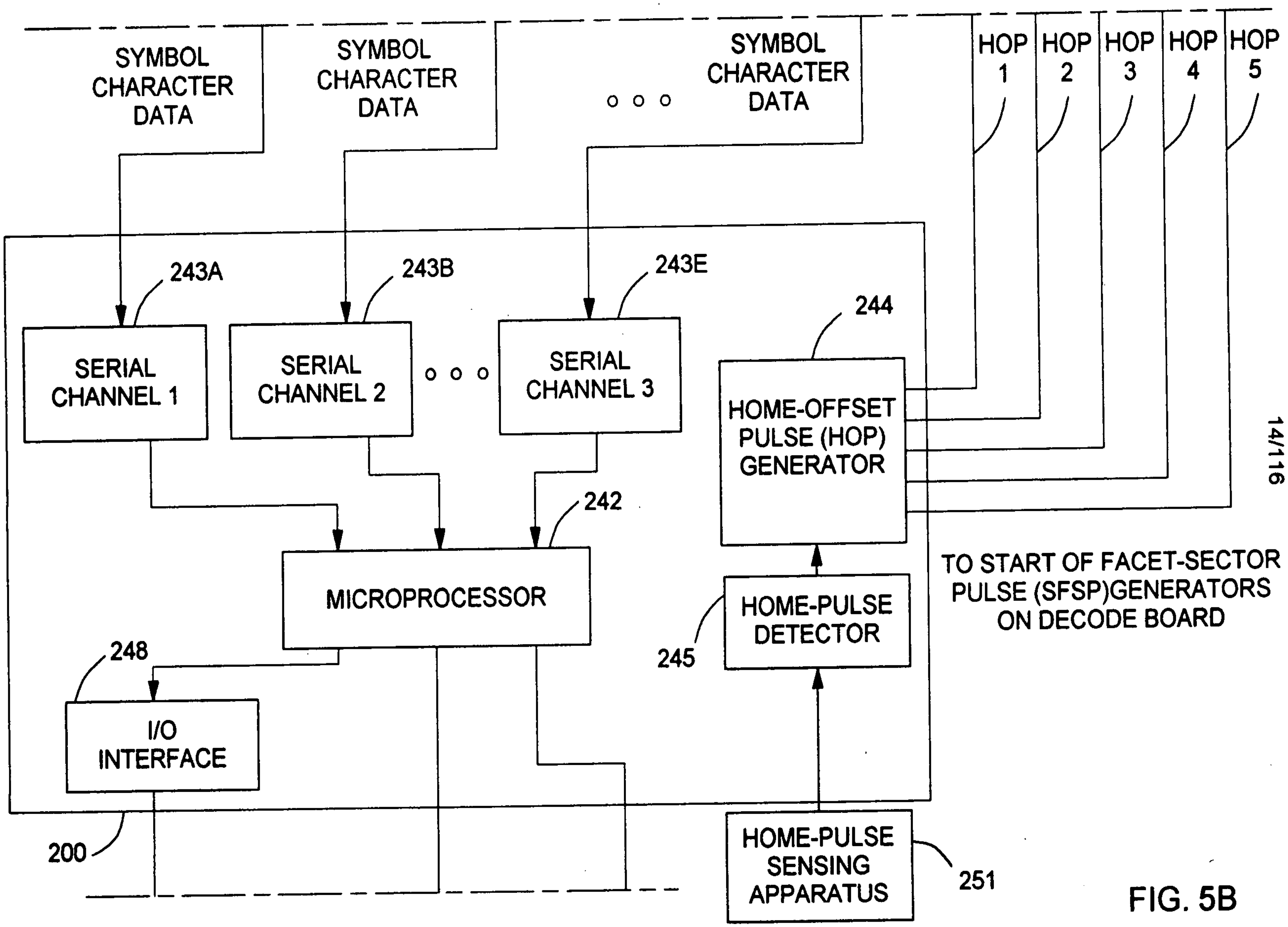

SYMBOL CHARACTER DATA
SYMBOL CHARACTER DATA
SYMBOL CHARACTER DATA
HOP 1
HOP 2
HOP 3
HOP 4
HOP 5
243A
243B
243E
244
SERIAL CHANNEL 1
SERIAL CHANNEL 2
SERIAL CHANNEL 3
HOME-OFFSET PULSE (HOP) GENERATOR
242
MICROPROCESSOR
TO START OF FACET-SECTOR PULSE (SFSP)GENERATORS ON DECODE BOARD
248
I/O INTERFACE
HOME-PULSE DETECTOR
245
200
HOME-PULSE SENSING APPARATUS
251

FIG. 5B

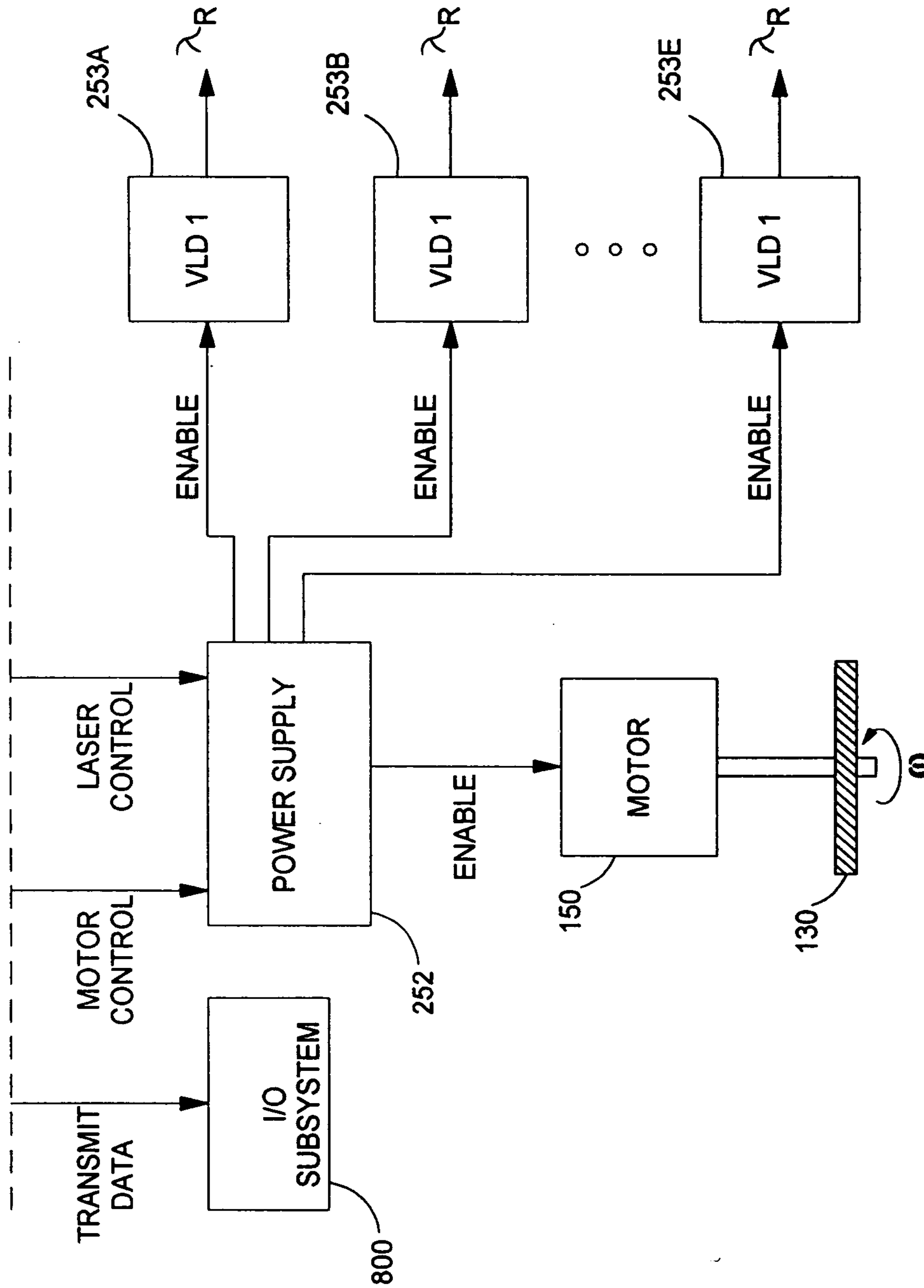

253A
253B
253E
λR
λR
λR
VLD 1
VLD 1
VLD 1
ENABLE
ENABLE
ENABLE
LASER CONTROL
MOTOR CONTROL
TRANSMIT DATA
POWER SUPPLY
ENABLE
MOTOR
I/O SUBSYSTEM
252
150
130
800
ω

FIG. 5C

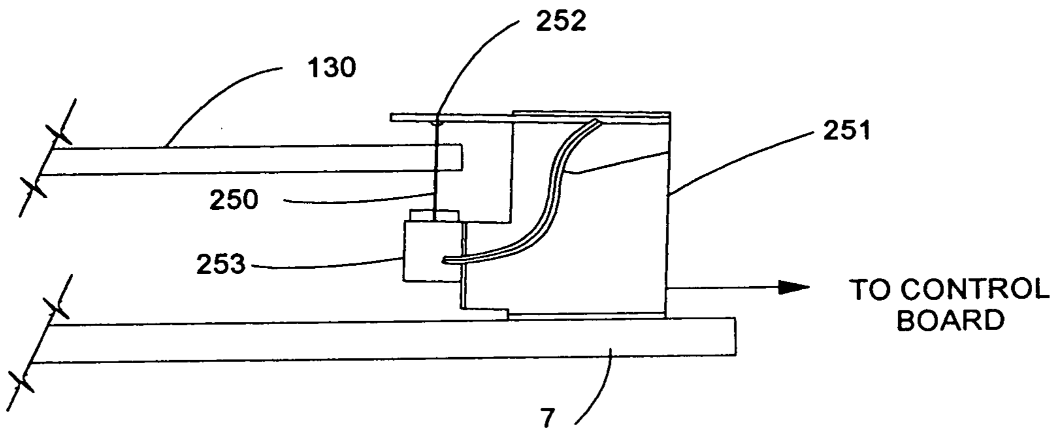


FIG. 6A

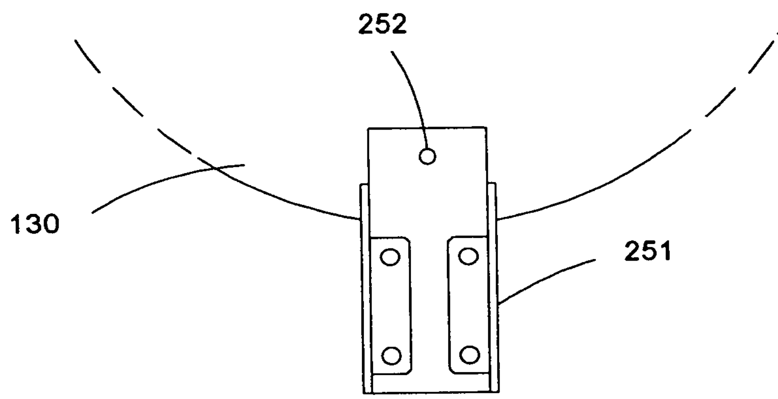


FIG. 6B

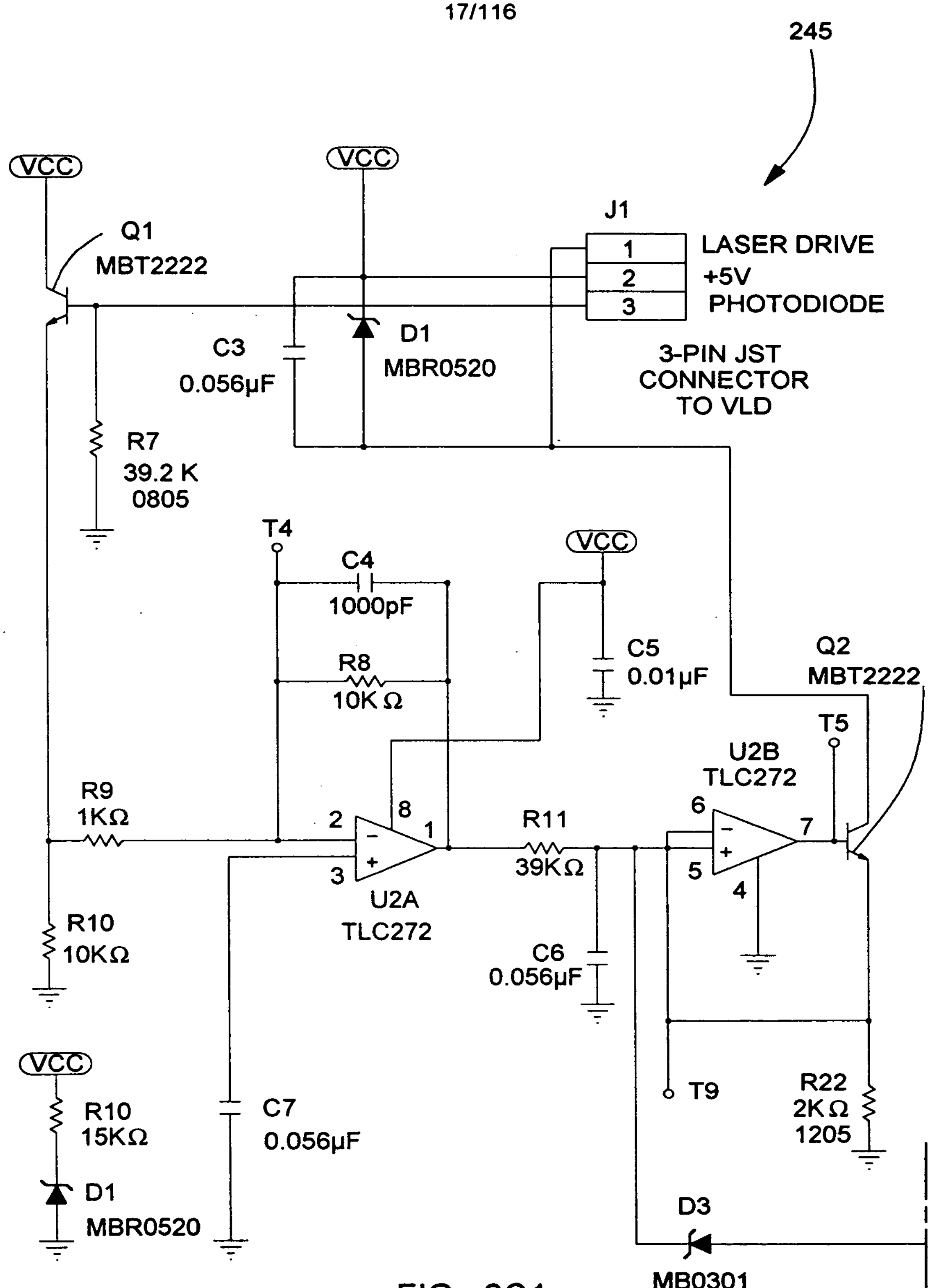

245
VCC
Q1
MBT2222
VCC
J1
1
2
3
LASER DRIVE
+5V
PHOTODIODE
C3
0.056µF
D1
MBR0520
3-PIN JST
CONNECTOR
TO VLD
R7
39.2 K
0805
T4
C4
1000pF
VCC
R8
10K Ω
C5
0.01µF
Q2
MBT2222
T5
U2B
TLC272
R9
1KΩ
2
8
1
R11
6
7
3
39KΩ
5
4
U2A
TLC272
R10
10KΩ
C6
0.056µF
VCC
R10
15KΩ
C7
0.056µF
T9
R22
2K Ω
1205
D1
MBR0520
D3
MB0301

FIG. 6C1

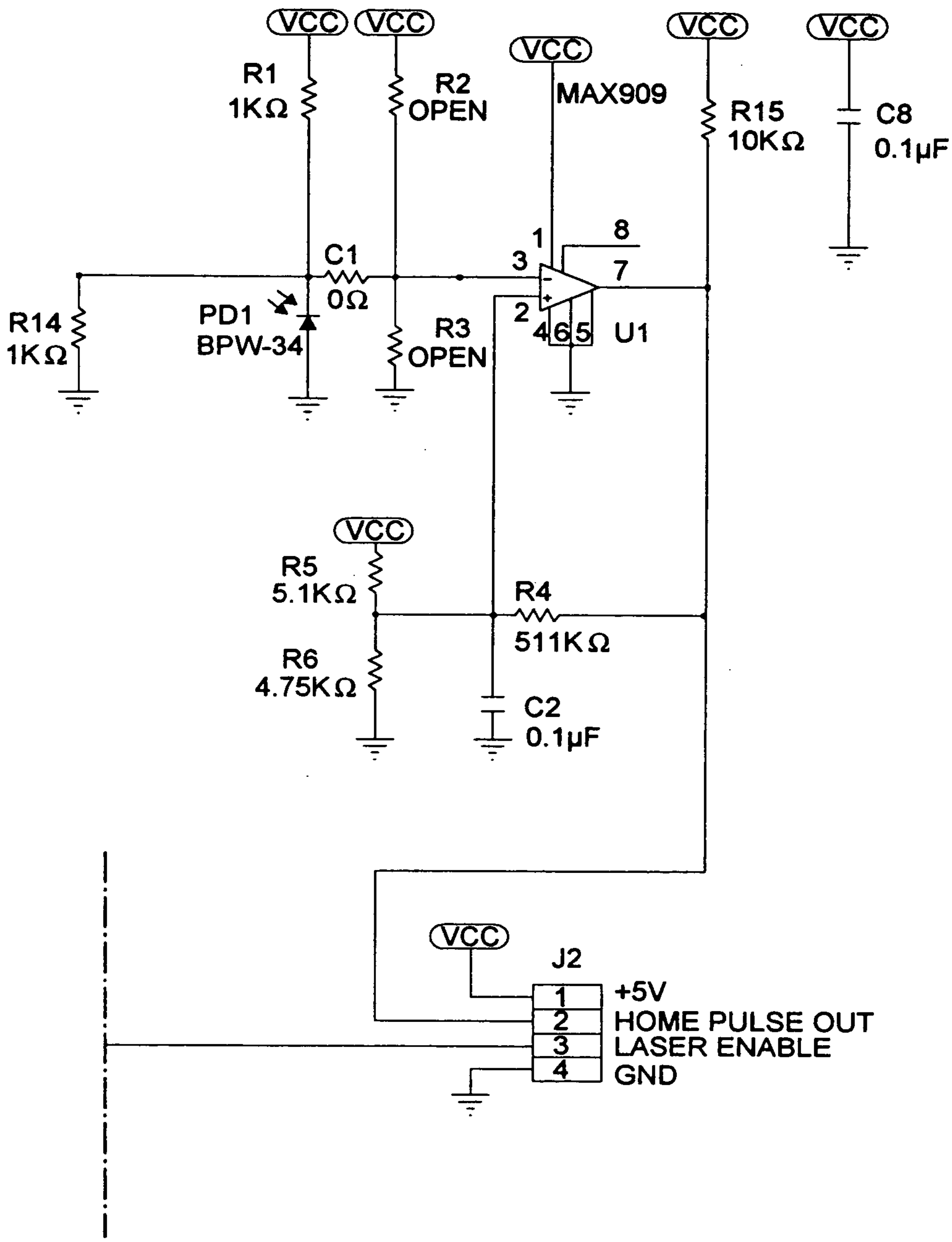
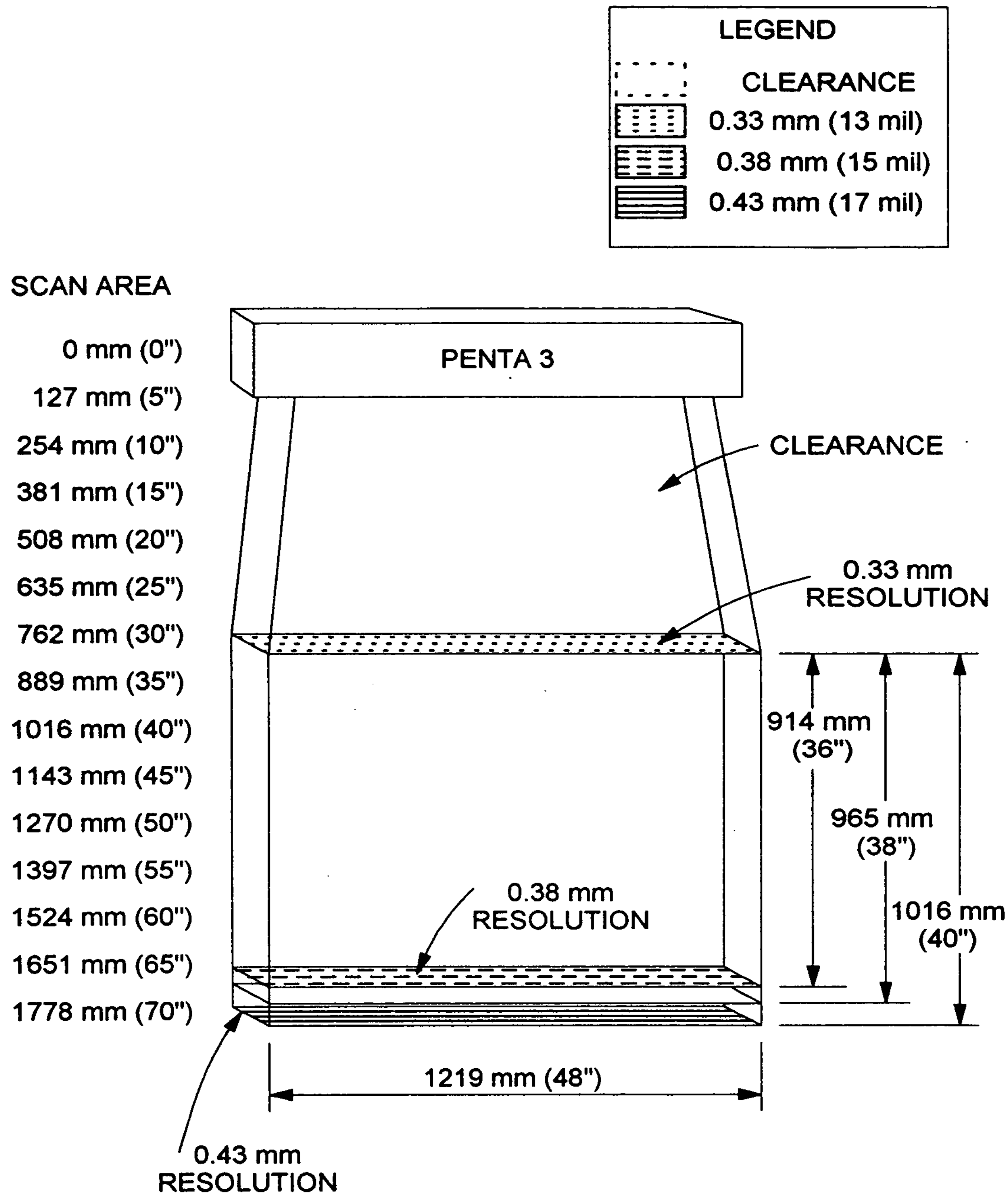

VCC
VCC
R1
1KΩ
R2
OPEN
VCC
MAX909
VCC
R15
10KΩ
VCC
C8
0.1μF
8
1
3
7
C1
0Ω
R14
1KΩ
PD1
BPW-34
R3
OPEN
2
4 6 5
U1
VCC
R5
5.1KΩ
R4
511KΩ
R6
4.75KΩ
C2
0.1μF
VCC
J2
1
2
3
4
+5V
HOME PULSE OUT
LASER ENABLE
GND

FIG. 6C2



LEGEND
CLEARANCE
0.33 mm (13 mil)
0.38 mm (15 mil)
0.43 mm (17 mil)
SCAN AREA
0 mm (0")
127 mm (5")
254 mm (10")
381 mm (15")
508 mm (20")
635 mm (25")
762 mm (30")
889 mm (35")
1016 mm (40")
1143 mm (45")
1270 mm (50")
1397 mm (55")
1524 mm (60")
1651 mm (65")
1778 mm (70")
PENTA 3
CLEARANCE
0.33 mm
RESOLUTION
914 mm
(36")
965 mm
(38")
1016 mm
(40")
0.38 mm
RESOLUTION
1219 mm (48")
0.43 mm
RESOLUTION

FIG. 7A

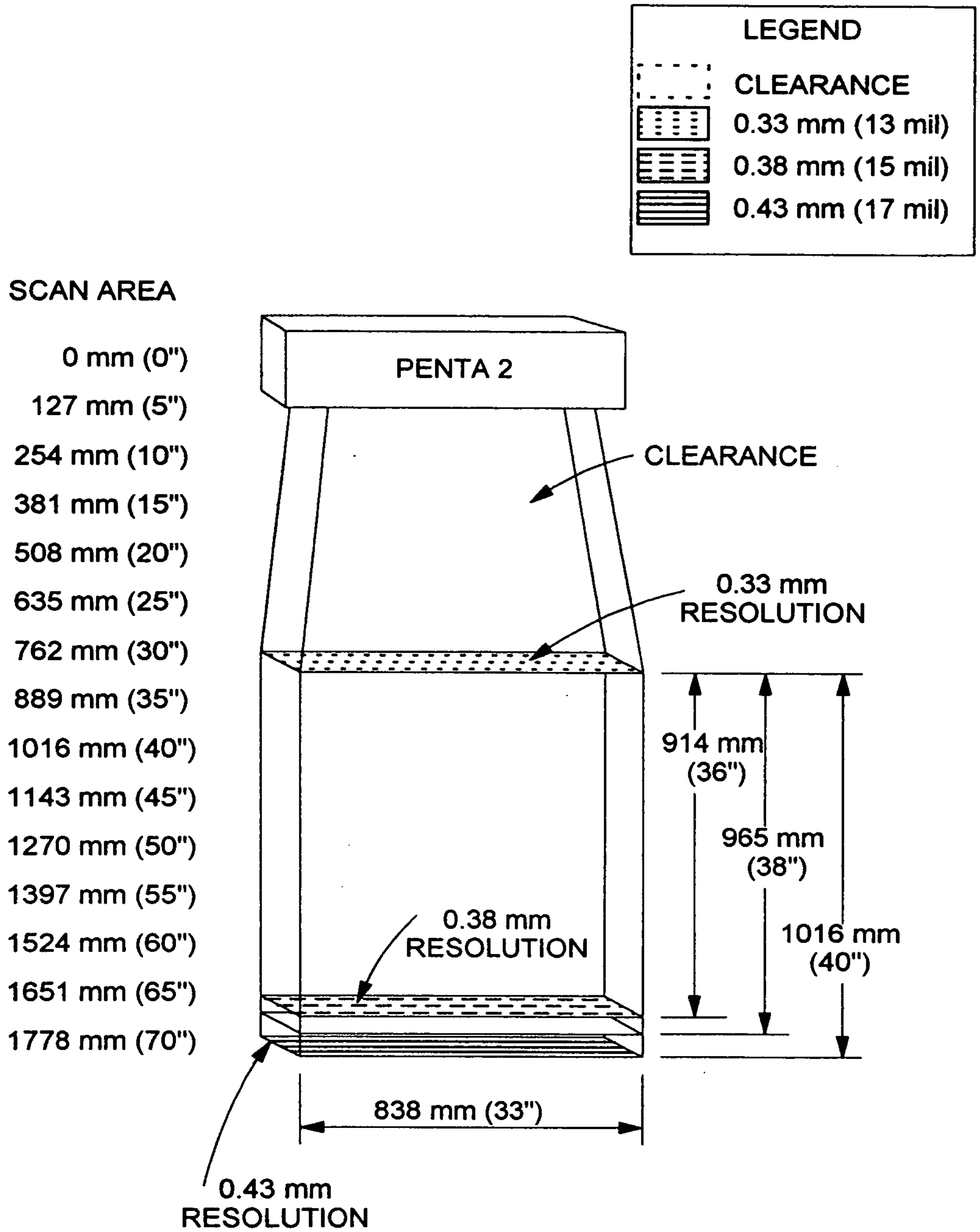

LEGEND
CLEARANCE
0.33 mm (13 mil)
0.38 mm (15 mil)
0.43 mm (17 mil)
SCAN AREA
0 mm (0")
127 mm (5")
254 mm (10")
381 mm (15")
508 mm (20")
635 mm (25")
762 mm (30")
889 mm (35")
1016 mm (40")
1143 mm (45")
1270 mm (50")
1397 mm (55")
1524 mm (60")
1651 mm (65")
1778 mm (70")
PENTA 2
CLEARANCE
0.33 mm RESOLUTION
914 mm (36")
965 mm (38")
1016 mm (40")
0.38 mm RESOLUTION
838 mm (33")
0.43 mm RESOLUTION

FIG. 7B

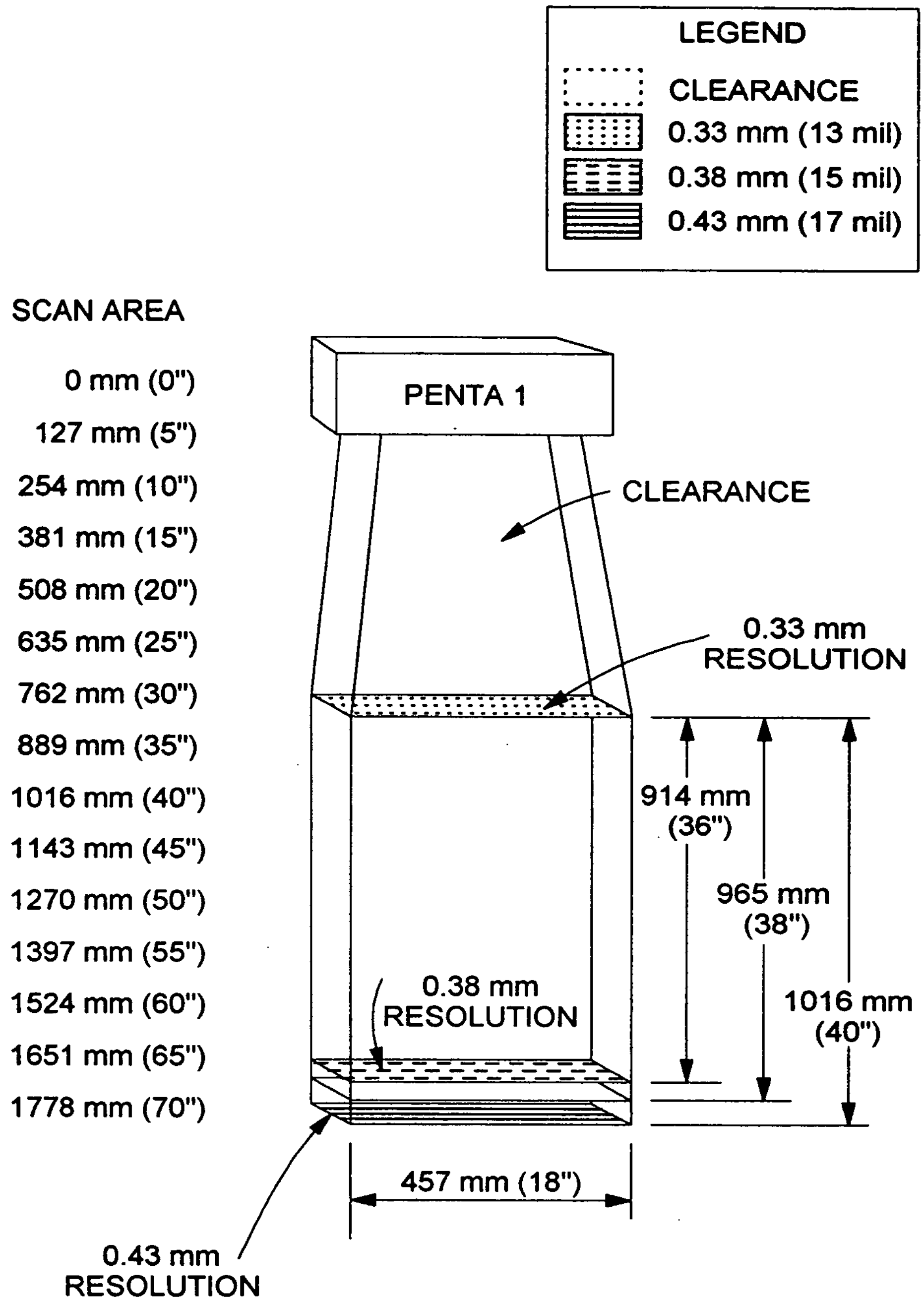

LEGEND
CLEARANCE
0.33 mm (13 mil)
0.38 mm (15 mil)
0.43 mm (17 mil)
SCAN AREA
0 mm (0")
127 mm (5")
254 mm (10")
381 mm (15")
508 mm (20")
635 mm (25")
762 mm (30")
889 mm (35")
1016 mm (40")
1143 mm (45")
1270 mm (50")
1397 mm (55")
1524 mm (60")
1651 mm (65")
1778 mm (70")
PENTA 1
CLEARANCE
0.33 mm RESOLUTION
914 mm (36")
965 mm (38")
1016 mm (40")
0.38 mm RESOLUTION
457 mm (18")
0.43 mm RESOLUTION

FIG. 7C

SPECIFICATIONS FOR PENTA 1, PENTA 2, PENTA 3 SCANNERS	
OPERATIONAL	
LIGHT SOURCE	5 VISIBLE LASER DIODES 858 + 5mm
LASER POWER	8.4mW (PEAK): LESS THAN 1 mW AVERAGE POWER
DEPTH OF SCAN FIELD	914mm (36") FOR 0.33 mm (13mil) BAR CODES 965mm (38") FOR 0.38 mm (15mil) BAR CODES 1,016mm (40") FOR 0.43 mm (17mil) BAR CODES
WIDTH OF SCAN FIELD	PENTA 1 : 457mm (18") PENTA 2 : 838mm (33") PENTA 3 : 1219mm (48")
SCAN SPEED	PENTA 1 : 6,930 SCAN LINES PER SECOND PENTA 2 : 13,860 SCAN LINES PER SECOND PENTA 3 : 20,790 SCAN LINES PER SECOND
SCAN PATTERN	OMNIDIRECTIONAL 5-SIDED PENTAGON SCAN PATTERN PENTA 1: 20 SCAN LINES REPEATED AT FOUR DISTANCES (80 TOTAL) PENTA 2: 40 SCAN LINES REPEATED AT FOUR DISTANCES (160 TOTAL) PENTA 3: 60 SCAN LINES REPEATED AT FOUR DISTANCES (240 TOTAL)
MINIMUM BAR WIDTH	0.33 mm (13mil)
DECODE CAPABILITY	AUTODISCRIMINATES ALL STANDARD BAR CODES
SYSTEM INTERFACES	RS 232. POINT TO POINT. RS422. LIGHT PEN EMULATION
PRINT CONTRAST	35% MINIMUM REFLECTANCE DIFFERENCE
NUMBER CHARACTERS READ	UP TO 60 DATA CHARACTERS. (MAXIMUM NUMBER WILL VARY BASED ON SYMBOLOGY AND DENSITY)
ASPECT RATIO	UP TO 2.6 TO 1

FIG. 8

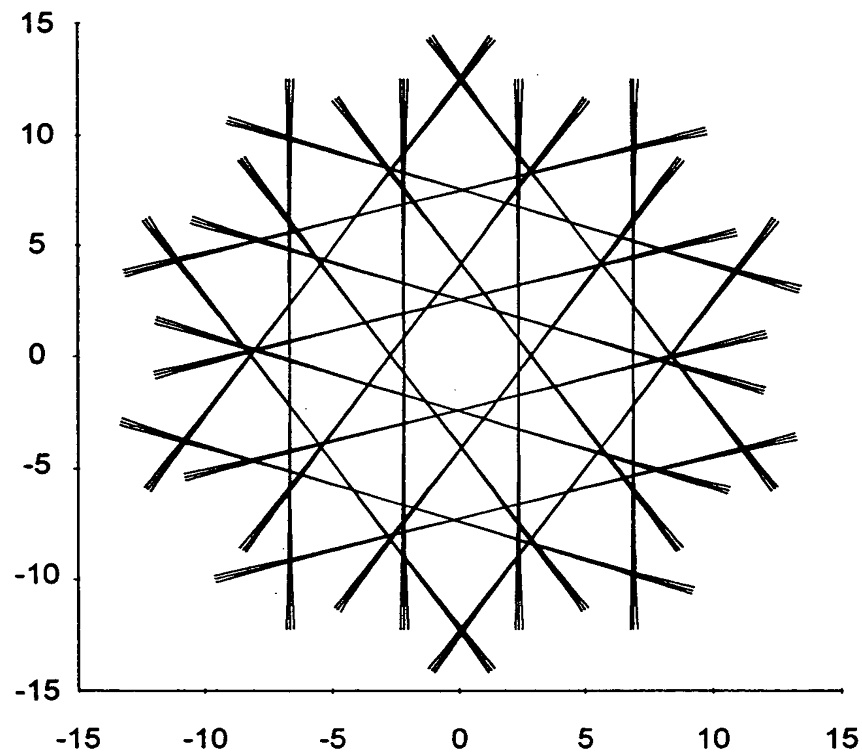


FIG. 9A

PENTA TRIPLE SCANNER FOCAL PLANE SCAN PATTERN

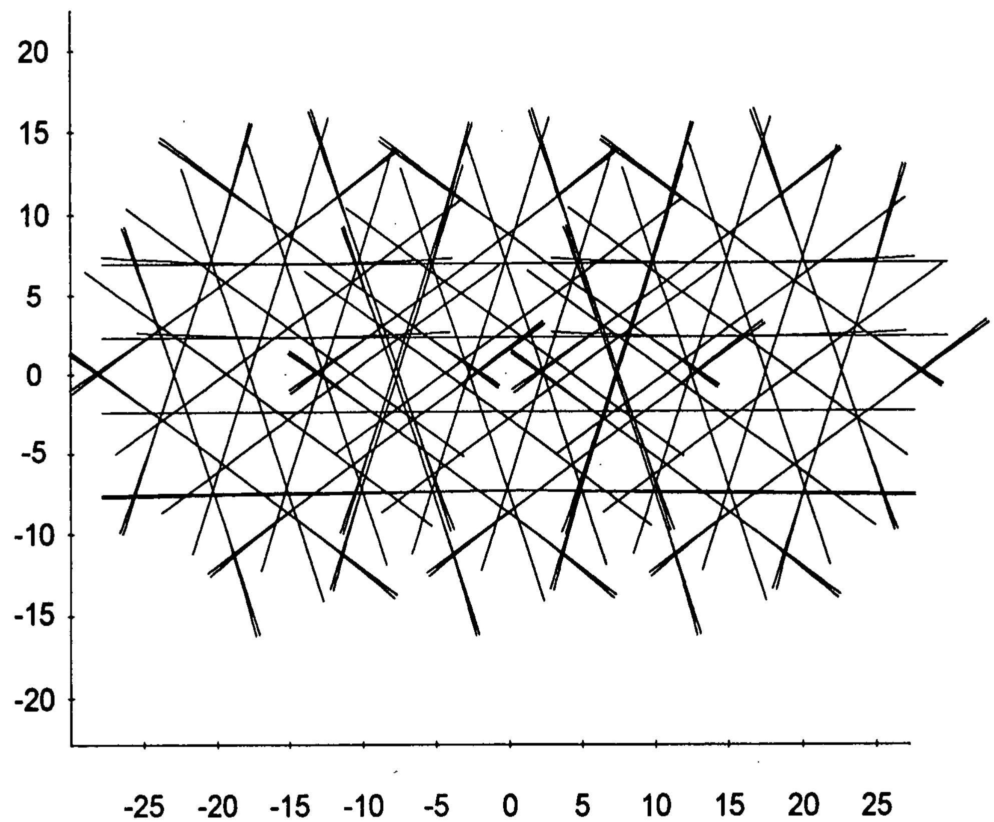


FIG. 9B

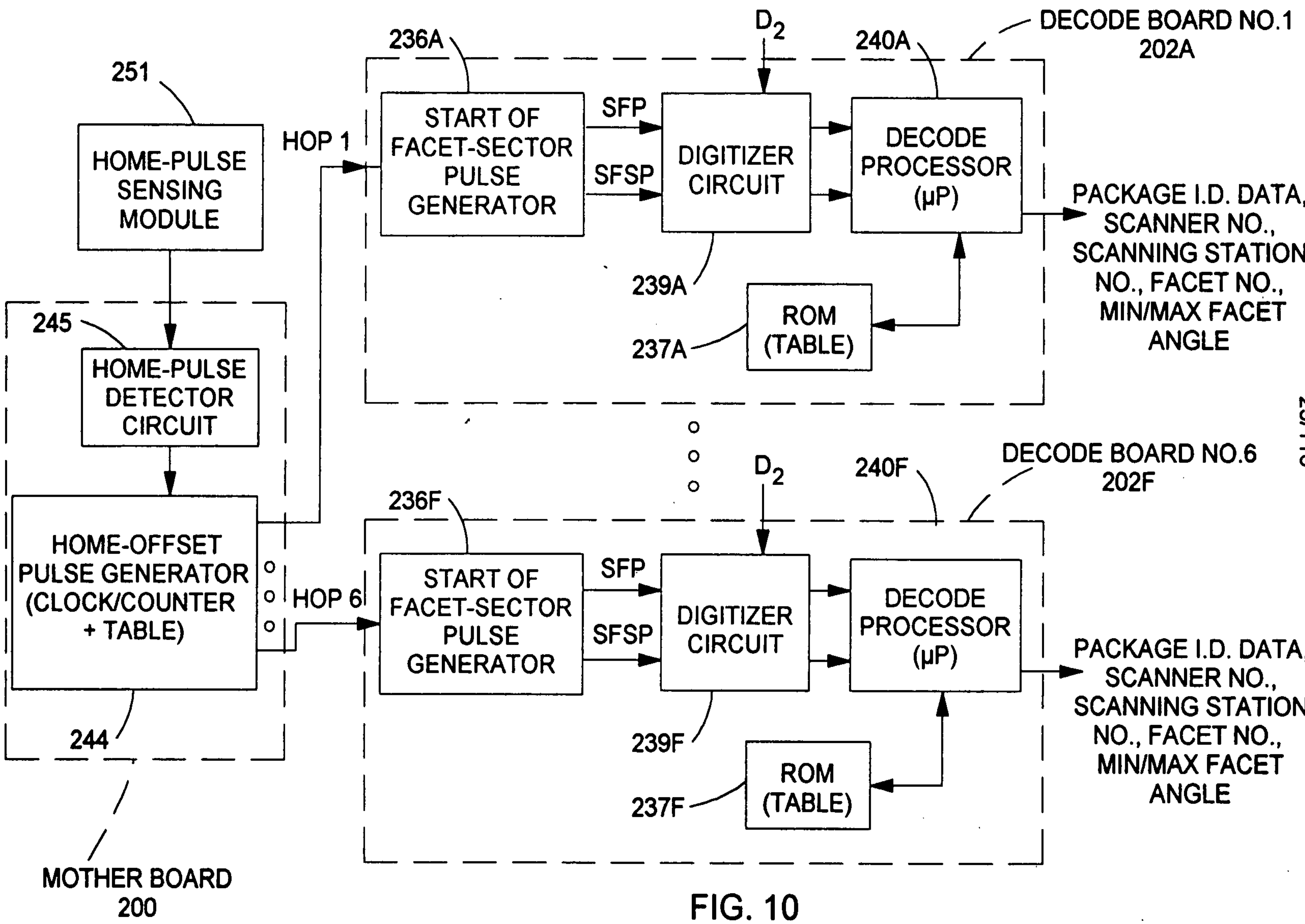

251
HOME-PULSE SENSING MODULE
245
HOME-PULSE DETECTOR CIRCUIT
HOME-OFFSET PULSE GENERATOR (CLOCK/COUNTER + TABLE)
244
MOTHER BOARD 200
HOP 1
HOP 6
236A
START OF FACET-SECTOR PULSE GENERATOR
SFP
SFSP
D_2
DIGITIZER CIRCUIT
239A
240A
DECODE PROCESSOR (µP)
ROM (TABLE)
237A
DECODE BOARD NO.1 202A
PACKAGE I.D. DATA, SCANNER NO., SCANNING STATION NO., FACET NO., MIN/MAX FACET ANGLE
236F
START OF FACET-SECTOR PULSE GENERATOR
SFP
SFSP
D_2
DIGITIZER CIRCUIT
239F
240F
DECODE PROCESSOR (µP)
ROM (TABLE)
237F
DECODE BOARD NO.6 202F
PACKAGE I.D. DATA, SCANNER NO., SCANNING STATION NO., FACET NO., MIN/MAX FACET ANGLE

FIG. 10

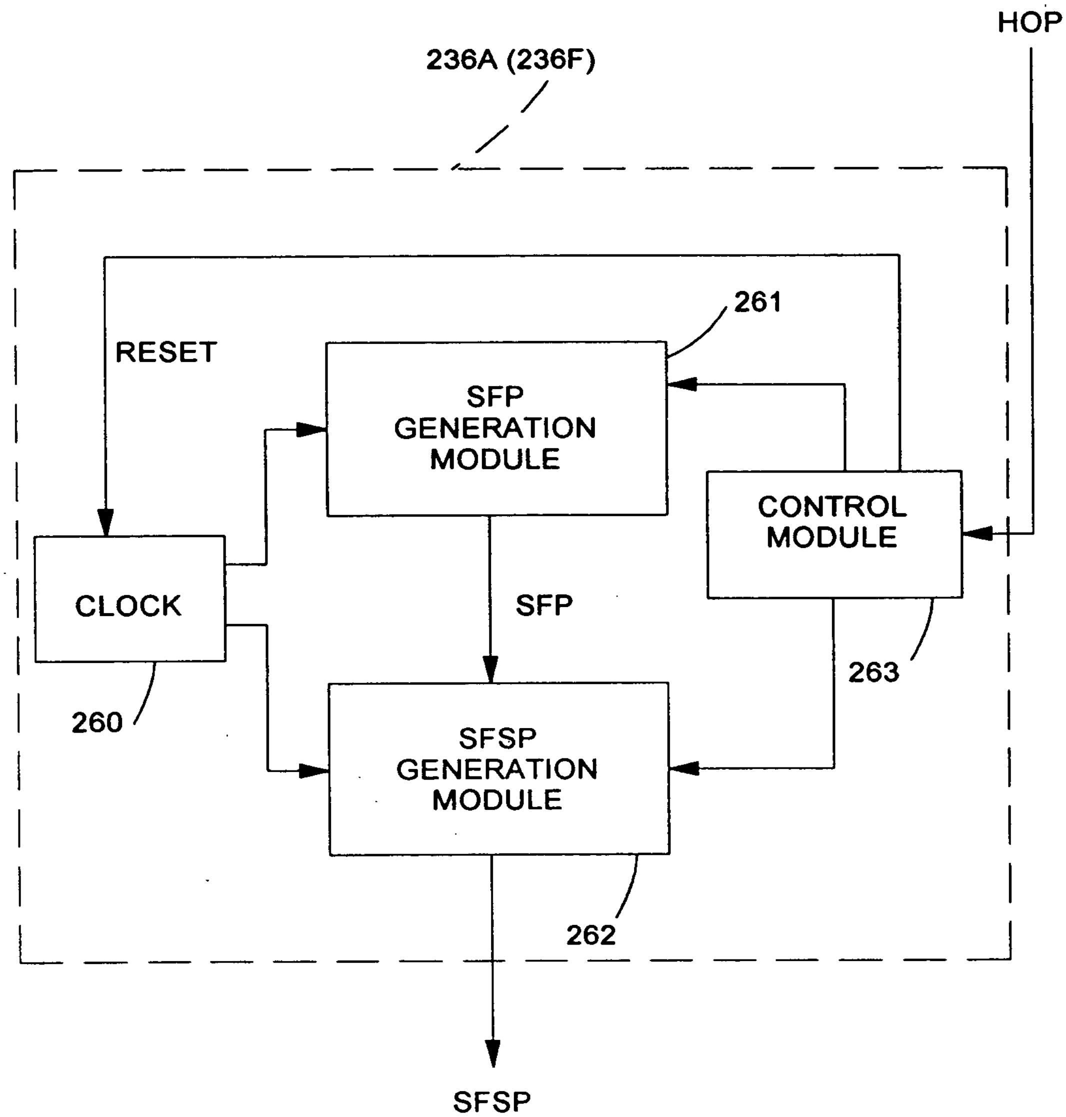

HOP
236A (236F)
RESET
261
SFP
GENERATION
MODULE
CONTROL
MODULE
CLOCK
SFP
263
260
SFSP
GENERATION
MODULE
262
SFSP

FIG. 10A

DATA TABLE EMBODIED IN SFP GENERATOR ON DECODE PROCESSOR BOARD

SCANNING FACET NO.	TRIGGERING EVENT WHEN THE CLOCK PULSE COUNT ATTAINS THE VALUE EQUAL TO THE COUNT VALUE SET FORTH BELOW	PULSE EVENT FROM SFP MODULE
12	7	SF12P
16	146	SF16P
4	271	SF4P
20	4467	SF20P
8	561	SF8P
11	716	SF11P
15	855	SF15P
3	980	SF3P
19	1155	SF19P
7	1270	SF7P
10	1425	SF10P
14	1564	SF14P
2	1689	SF2P
18	1864	SF18P
6	1979	SF6P
9	2134	SF9P
13	2273	SF13P
1	2398	SF1P
17	2573	SF17P
5	2688	SF5P

W = 5200 RPM
CLOCK PULSE WIDTH = 4 μSEC

FIG. 10B

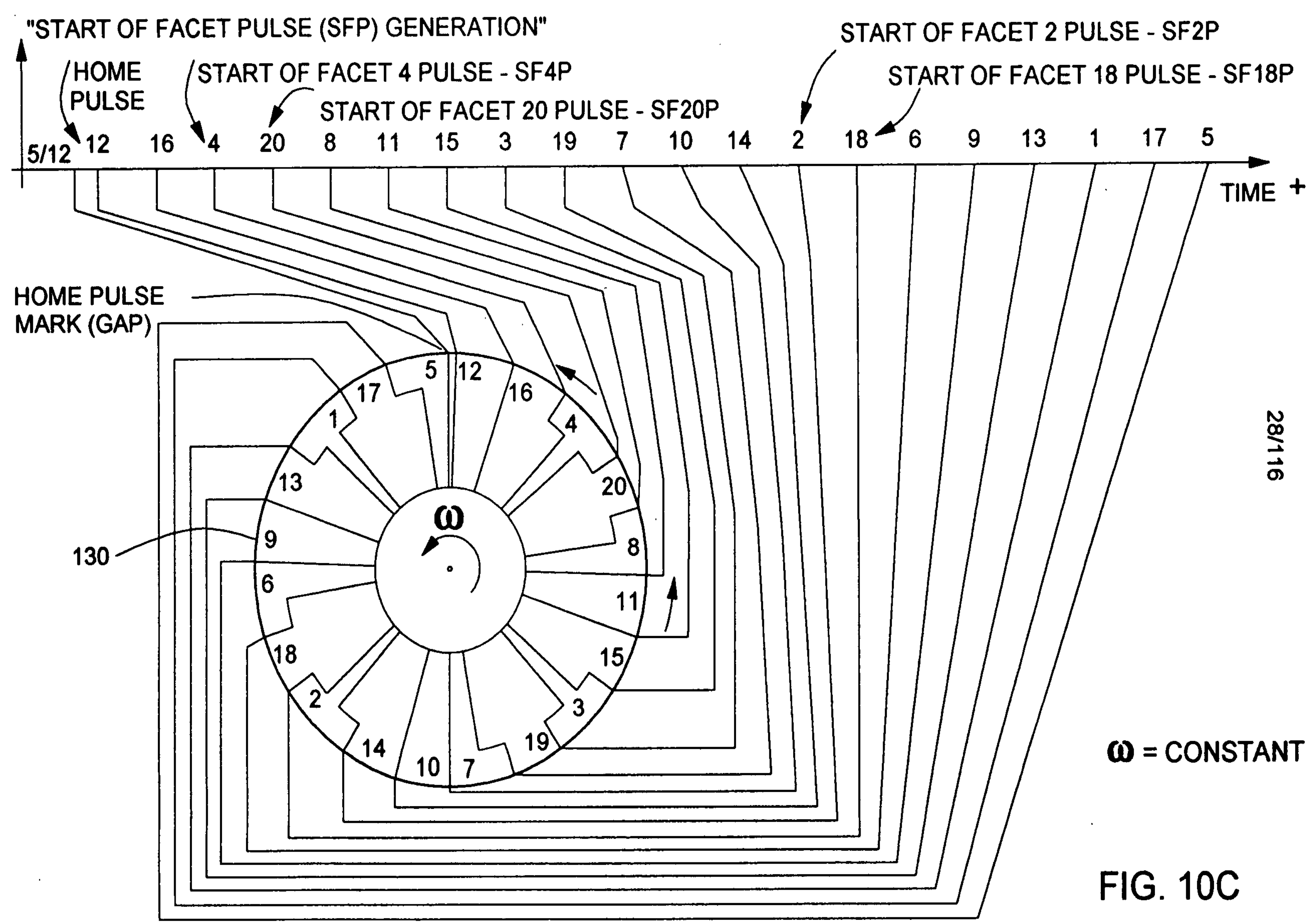

"START OF FACET PULSE (SFP) GENERATION"
HOME PULSE
START OF FACET 4 PULSE - SF4P
START OF FACET 20 PULSE - SF20P
START OF FACET 2 PULSE - SF2P
START OF FACET 18 PULSE - SF18P
5/12
12 16 4 20 8 11 15 3 19 7 10 14 2 18 6 9 13 1 17 5
TIME +
HOME PULSE MARK (GAP)
130
ω
ω = CONSTANT

FIG. 10C

TABLE EMBODIED IN SFSP GENERATOR DECODE PROCESSOR BOARD

SCANNING FACET NO.	SFSP TRIGGERING EVENT	PULSE EVENT FROM SFSP MODULE .
12	RULES 1 - 4 IN FIGS.	SFSP 12/1P SFSP 12/2P SFSP 12/3P SFSP 12/4P
16	RULES 1 - 4 IN FIGS.	SFSP 16/1P SFSP 16/2P SFSP 16/3P SFSP 16/4P
4	RULES 1 - 4 IN FIGS.	SFSP 4/1P SFSP 4/2P SFSP 4/3P SFSP 4/4P
20	RULES 1 - 4 IN FIGS.	SFSP 20/1P SFSP 20/2P SFSP 20/3P SFSP 20/4P
8	RULES 1 - 4 IN FIGS.	SFSP 8/1P SFSP 8/2P SFSP 8/3P SFSP 8/4P
11	RULES 1 - 4 IN FIGS.	SFSP 11/1P SFSP 11/2P SFSP 11/3P SFSP 11/4P
o o o		
17	RULES 1 - 4 IN FIGS.	SFSP 17/1P SFSP 17/2P SFSP 17/3P SFSP 17/4P
5	RULES 1 - 4 IN FIGS.	SFSP 5/1P SFSP 5/2P SFSP 5/3P SFSP 5/4P

FIG. 10D

RULE 1: FOR GENERATING SFSP/1P TYPE PULSES

FOR EACH FACET X BEFORE WHICH IS LOCATED FACET X-1 AND BEYOND WHICH IS LOCATED FACET X+1 (ABOUT THE SCANNING DISC), THE SFSP GENERATION MODULE GENERATES SFSX/1P TYPE PULSES WHEN THE COUNT IS EQUAL TO:

COUNT (SFSP)

RULE 2: FOR GENERATING SFSX/2P TYPE PULSES

FOR EACH FACET X BEFORE WHICH IS LOCATED FACET X-1 AND BEYOND WHICH IS LOCATED FACET X+1 (ABOUT THE SCANNING DISC), THE SFSP GENERATION MODULE GENERATES SFSX/2P TYPE PULSES WHEN THE COUNT IS EQUAL TO:

$$\text{COUNT (SFSP)} +1 \left[\frac{\text{COUNT (SFX+1P)} - \text{COUNT (SFXP)}}{4} \right]$$

FIG. 10E1

RULE 3: FOR GENERATING SFSP/3P TYPE PULSES

FOR EACH FACET X BEFORE WHICH IS LOCATED FACET X-1 AND BEYOND WHICH IS LOCATED FACET X+1 (ABOUT THE SCANNING DISC), THE SFSP GENERATION MODULE GENERATES SFSX/3 TYPE PULSES WHEN THE COUNT IS EQUAL TO:

$$\text{COUNT (SFSP)} + 2\left[\frac{\text{COUNT (SFX+1P)} - \text{COUNT (SFXP)}}{4}\right]$$

RULE4: FOR GENERATING SFSX/4P TYPE PULSES

FOR EACH FACET X BEFORE WHICH IS LOCATED FACET X-1 AND BEYOND WHICH IS LOCATED FACET X+1 (ABOUT THE SCANNING DISC), THE SFSP GENERATION MODULE GENERATES SFSX/4 TYPE PULSES WHEN THE COUNT IS EQUAL TO:

$$\text{COUNT (SFSP)} + 3\left[\frac{\text{COUNT (SFX+1P)} - \text{COUNT (SFXP)}}{4}\right]$$

FIG. 10E2

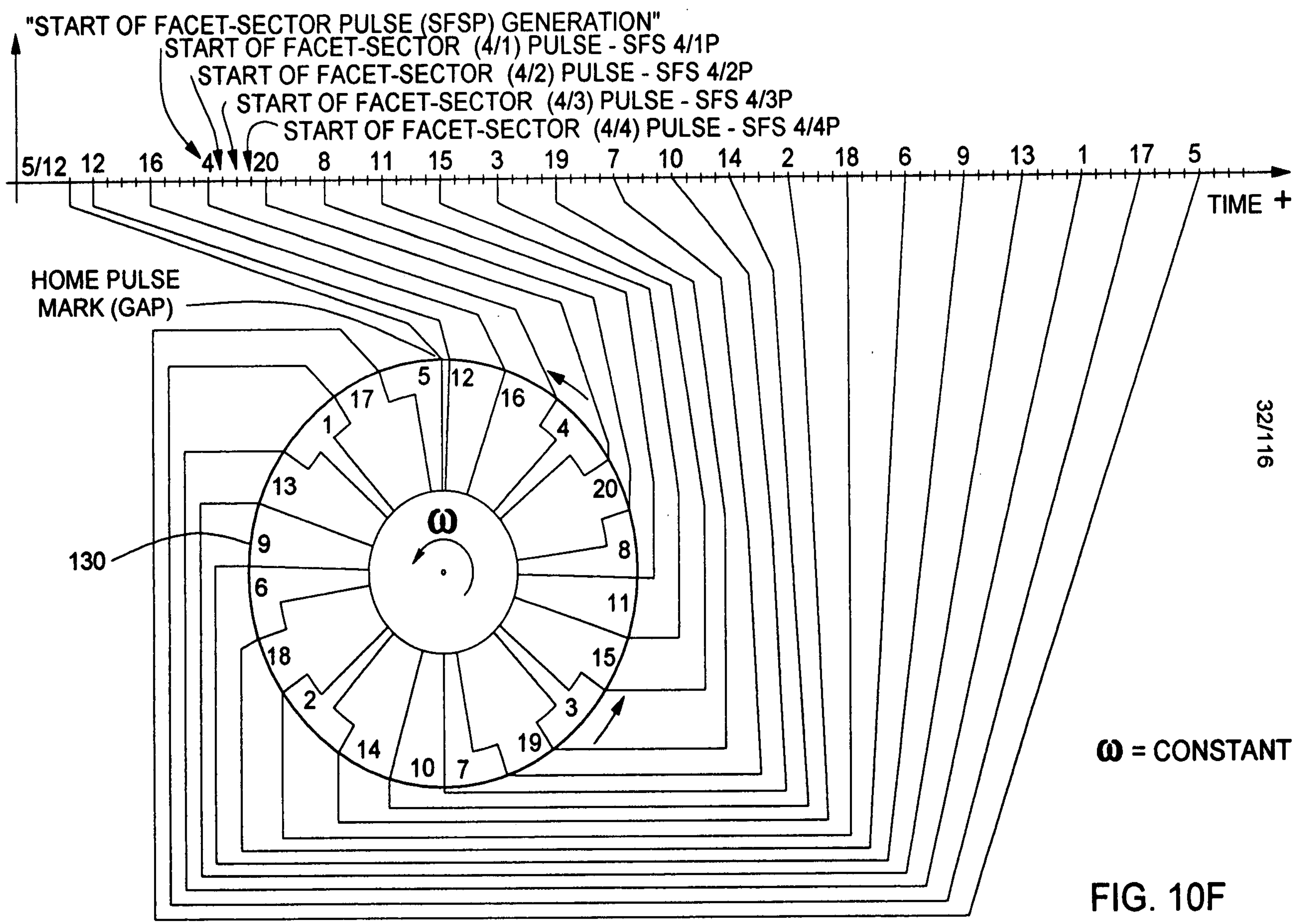

"START OF FACET-SECTOR PULSE (SFSP) GENERATION"
START OF FACET-SECTOR (4/1) PULSE - SFS 4/1P
START OF FACET-SECTOR (4/2) PULSE - SFS 4/2P
START OF FACET-SECTOR (4/3) PULSE - SFS 4/3P
START OF FACET-SECTOR (4/4) PULSE - SFS 4/4P
5/12 12 16 4 20 8 11 15 3 19 7 10 14 2 18 6 9 13 1 17 5
TIME +
HOME PULSE MARK (GAP)
130
5 12 16 4 20 8 11 15 3 19 7 10 14 2 18 6 9 13 1 17
ω
ω = CONSTANT

FIG. 10F

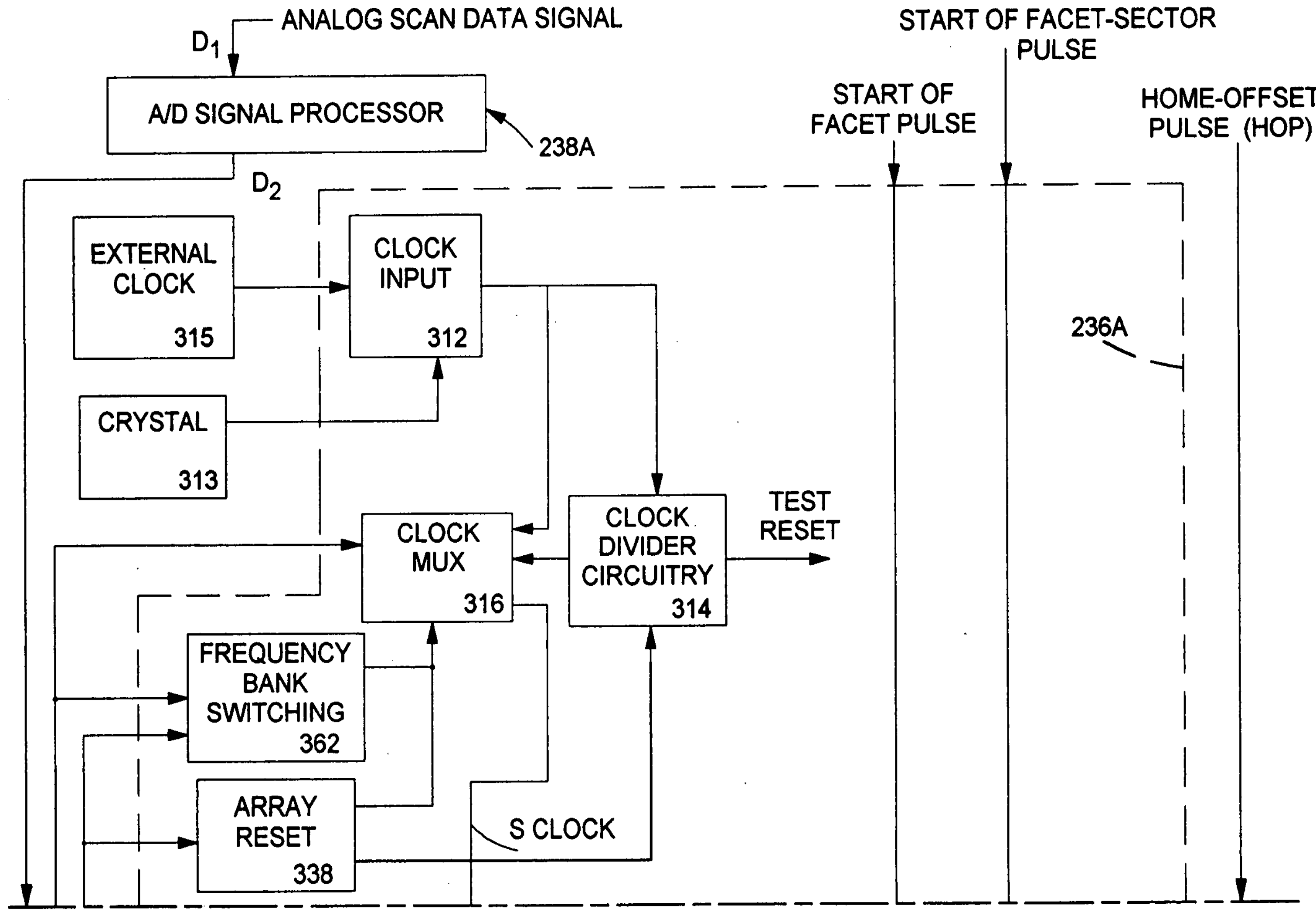
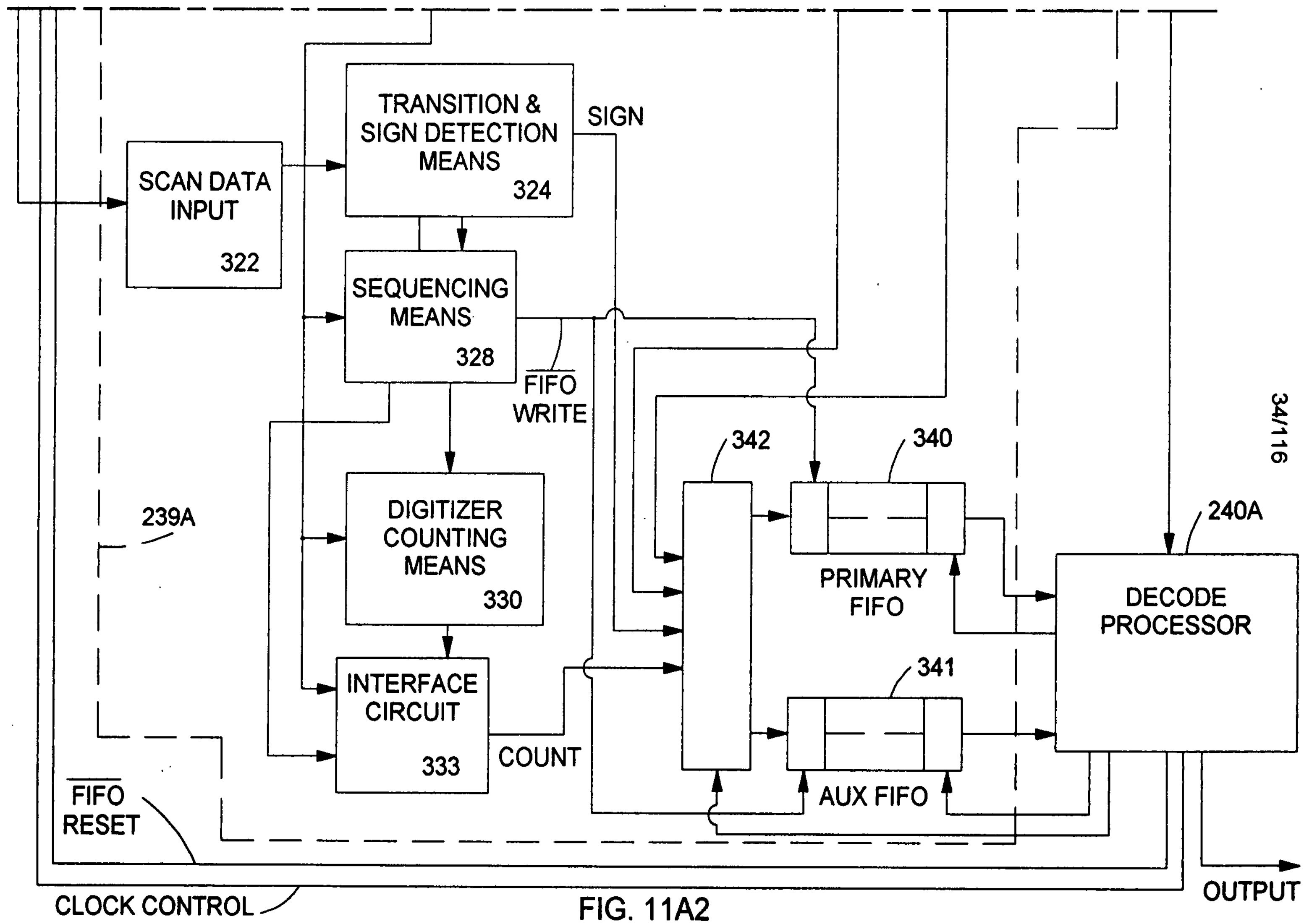

ANALOG SCAN DATA SIGNAL
D_1
A/D SIGNAL PROCESSOR
238A
D_2
START OF FACET-SECTOR PULSE
START OF FACET PULSE
HOME-OFFSET PULSE (HOP)
EXTERNAL CLOCK 315
CLOCK INPUT 312
CRYSTAL 313
236A
CLOCK MUX 316
CLOCK DIVIDER CIRCUITRY 314
TEST RESET
FREQUENCY BANK SWITCHING 362
ARRAY RESET 338
S CLOCK

FIG. 11A1



SCAN DATA INPUT
322
TRANSITION & SIGN DETECTION MEANS
324
SIGN
SEQUENCING MEANS
328
$\overline{\text{FIFO}}$ WRITE
DIGITIZER COUNTING MEANS
330
INTERFACE CIRCUIT
333
COUNT
342
340
PRIMARY FIFO
341
AUX FIFO
240A
DECODE PROCESSOR
OUTPUT
239A
$\overline{\text{FIFO}}$ RESET
CLOCK CONTROL

FIG. 11A2

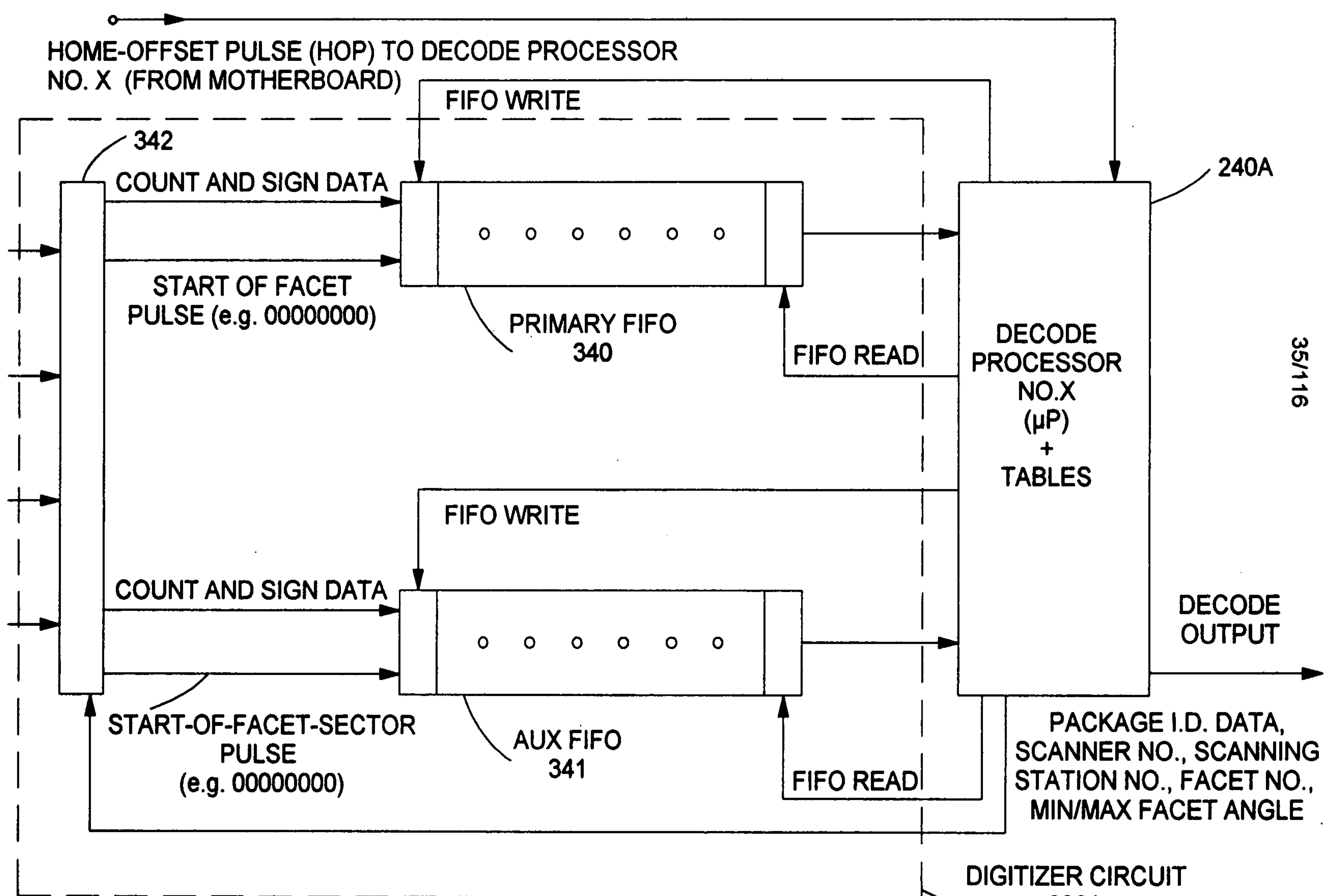

HOME-OFFSET PULSE (HOP) TO DECODE PROCESSOR NO. X (FROM MOTHERBOARD)
FIFO WRITE
342
COUNT AND SIGN DATA
START OF FACET PULSE (e.g. 00000000)
PRIMARY FIFO 340
FIFO READ
DECODE PROCESSOR NO.X (µP) + TABLES
240A
FIFO WRITE
COUNT AND SIGN DATA
START-OF-FACET-SECTOR PULSE (e.g. 00000000)
AUX FIFO 341
FIFO READ
DECODE OUTPUT
PACKAGE I.D. DATA, SCANNER NO., SCANNING STATION NO., FACET NO., MIN/MAX FACET ANGLE
DIGITIZER CIRCUIT 239A

FIG. 11B

SCANNER NO.	TOTAL NO. OF FACETS ON DISC
NO. OF SECTORS / FACET	SCANNING STATION NO.

FIG. 11C1

SCANNING FACET NO.	TRIGGERING EVENT WHEN THE CLOCK PULSE COUNT ATTAINS THE VALUE EQUAL TO THE COUNT VALUE SET FORTH BELOW	PULSE EVENT FROM SFP MODULE
12	7	SF12P
16	146	SF16P
4	271	SF4P
20	4467	SF20P
8	561	SF8P
11	716	SF11P
15	855	SF15P
3	980	SF3P
19	1155	SF19P
7	1270	SF7P
10	1425	SF10P
14	1564	SF14P
2	1689	SF2P
18	1864	SF18P
6	1979	SF6P
9	2134	SF9P
13	2273	SF13P
1	2398	SF1P
17	2573	SF17P
5	2688	SF5P

TABLES EMBODIED IN DECODE PROCESSOR
CLOCK PULSE WIDTH = 4 μSEC
W = 5200 RPM

FIG. 11C2

TABLE EMBODIED IN DECODE PROCESSOR

SCANNING FACET NO.	SFS TRIGGERING EVENT	PULSE EVENT FROM SFSP MODULE .	MINIMUM AND MAXIMUM FACET ANGLES CORRESPONDING TO FACET-SECTOR IDENTIFIED BY SFSP EVENT
12	RULES 1 - 4 IN FIGS.	SFSP 12/1P	θROT MIN, θROT MAX
		SFSP 12/2P	
		SFSP 12/3P	
		SFSP 12/4P	
16	RULES 1 - 4 IN FIGS.	SFSP 16/1P	
		SFSP 16/2P	
		SFSP 16/3P	
		SFSP 16/4P	
4	RULES 1 - 4 IN FIGS.	SFSP 4/1P	
		SFSP 4/2P	
		SFSP 4/3P	
		SFSP 4/4P	
20	RULES 1 - 4 IN FIGS.	SFSP 20/1P	
		SFSP 20/2P	
		SFSP 20/3P	
		SFSP 20/4P	
8	RULES 1 - 4 IN FIGS.	SFSP 8/1P	
		SFSP 8/2P	
		SFSP 8/3P	
		SFSP 8/4P	
11	RULES 1 - 4 IN FIGS.	SFSP 11/1P	
		SFSP 11/2P	
		SFSP 11/3P	
		SFSP 11/4P	
	o o o		
17	RULES 1 - 4 IN FIGS.	SFSP 17/1P	
		SFSP 17/2P	
		SFSP 17/3P	
		SFSP 17/4P	
5	RULES 1 - 4 IN FIGS.	SFSP 5/1P	
		SFSP 5/2P	
		SFSP 5/3P	
		SFSP 5/4P	

FIG. 11D

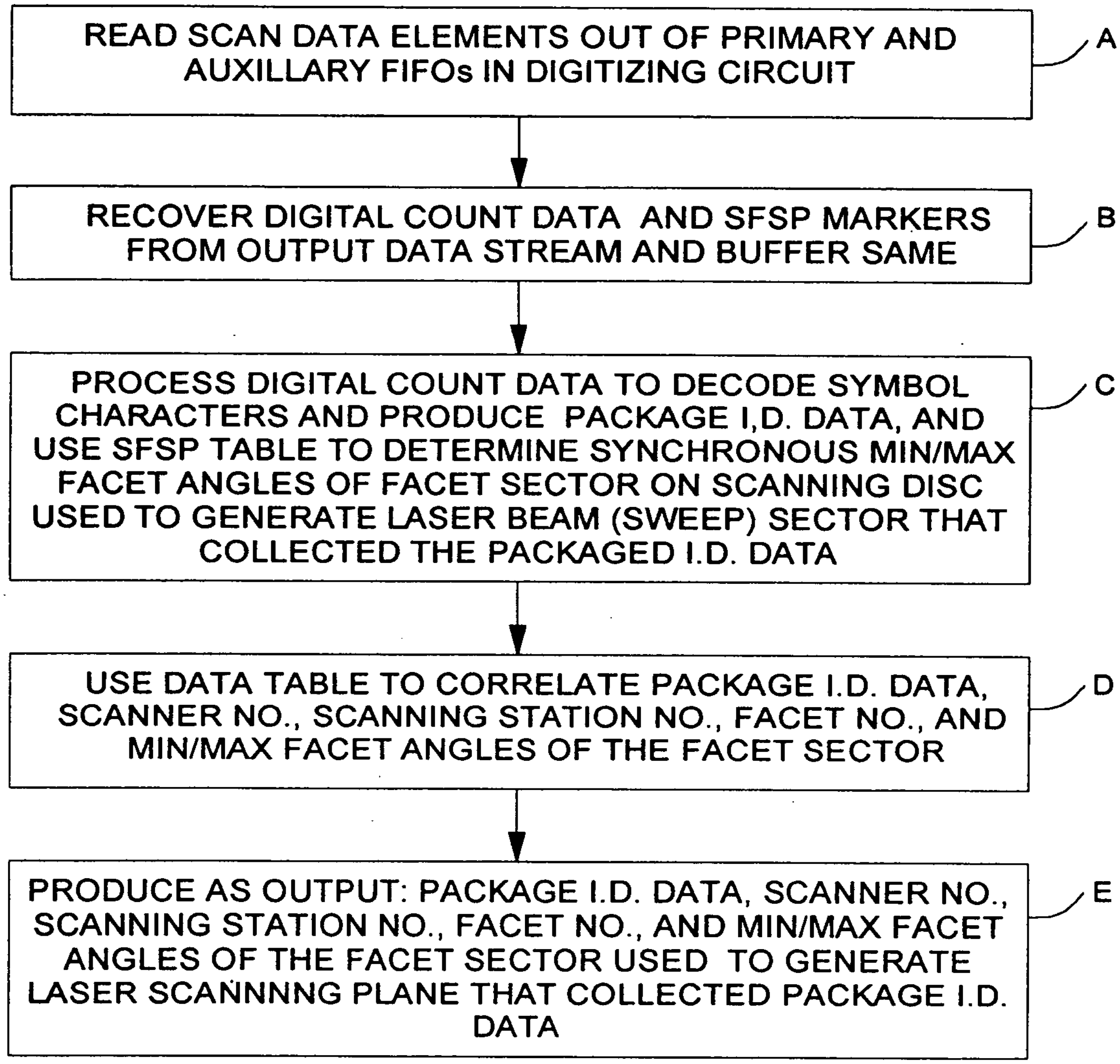

READ SCAN DATA ELEMENTS OUT OF PRIMARY AND AUXILLARY FIFOs IN DIGITIZING CIRCUIT
A
RECOVER DIGITAL COUNT DATA AND SFSP MARKERS FROM OUTPUT DATA STREAM AND BUFFER SAME
B
PROCESS DIGITAL COUNT DATA TO DECODE SYMBOL CHARACTERS AND PRODUCE PACKAGE I,D. DATA, AND USE SFSP TABLE TO DETERMINE SYNCHRONOUS MIN/MAX FACET ANGLES OF FACET SECTOR ON SCANNING DISC USED TO GENERATE LASER BEAM (SWEEP) SECTOR THAT COLLECTED THE PACKAGED I.D. DATA
C
USE DATA TABLE TO CORRELATE PACKAGE I.D. DATA, SCANNER NO., SCANNING STATION NO., FACET NO., AND MIN/MAX FACET ANGLES OF THE FACET SECTOR
D
PRODUCE AS OUTPUT: PACKAGE I.D. DATA, SCANNER NO., SCANNING STATION NO., FACET NO., AND MIN/MAX FACET ANGLES OF THE FACET SECTOR USED TO GENERATE LASER SCANNNNG PLANE THAT COLLECTED PACKAGE I.D. DATA
E

FIG. 11E

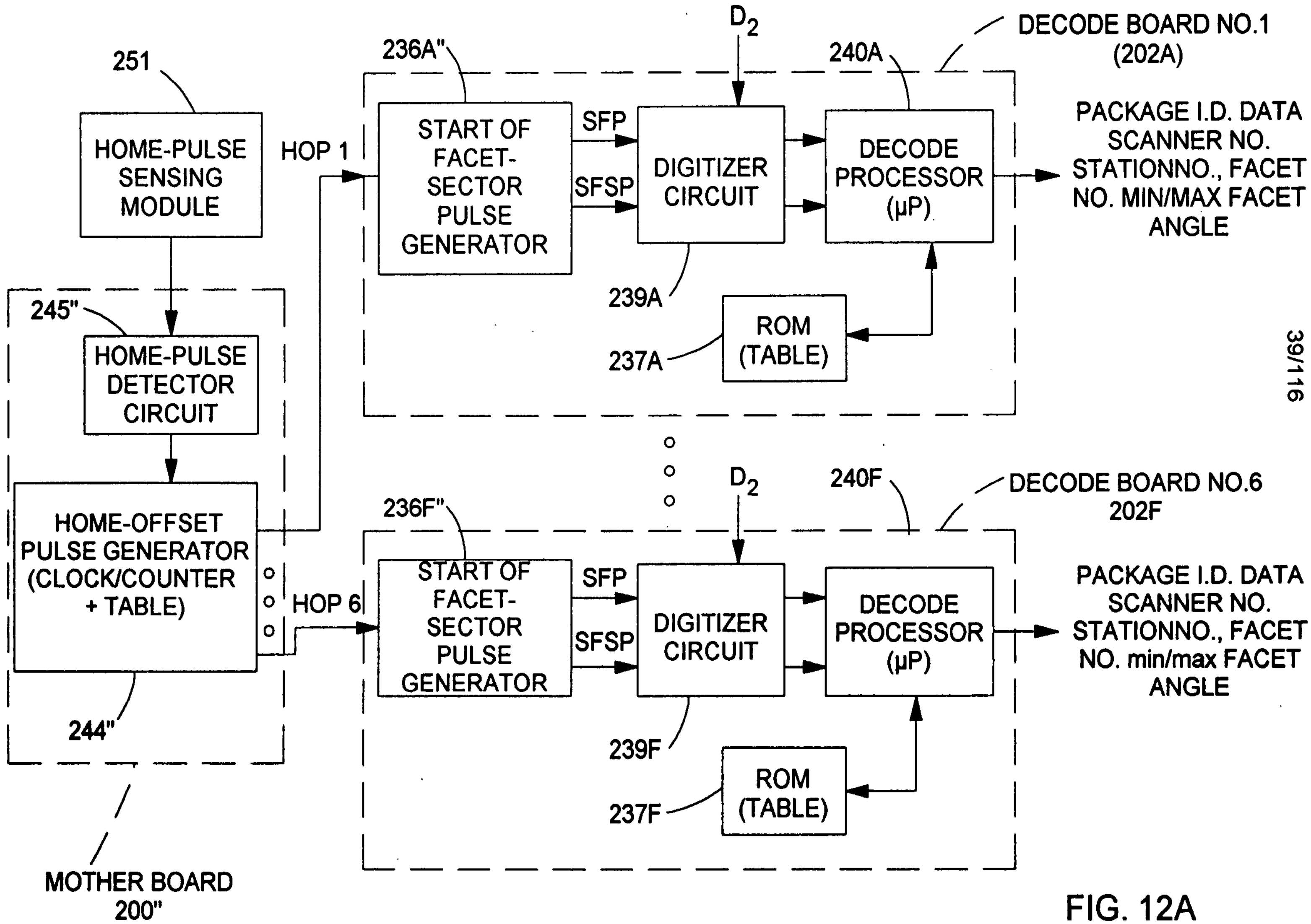

251
HOME-PULSE SENSING MODULE
245"
HOME-PULSE DETECTOR CIRCUIT
HOME-OFFSET PULSE GENERATOR (CLOCK/COUNTER + TABLE)
244"
MOTHER BOARD 200"
HOP 1
HOP 6
236A"
START OF FACET-SECTOR PULSE GENERATOR
SFP
SFSP
D_2
DIGITIZER CIRCUIT
239A
DECODE PROCESSOR (μP)
240A
ROM (TABLE)
237A
DECODE BOARD NO.1 (202A)
PACKAGE I.D. DATA SCANNER NO. STATIONNO., FACET NO. MIN/MAX FACET ANGLE
236F"
START OF FACET-SECTOR PULSE GENERATOR
SFP
SFSP
D_2
DIGITIZER CIRCUIT
239F
DECODE PROCESSOR (μP)
240F
ROM (TABLE)
237F
DECODE BOARD NO.6 202F
PACKAGE I.D. DATA SCANNER NO. STATIONNO., FACET NO. min/max FACET ANGLE

FIG. 12A

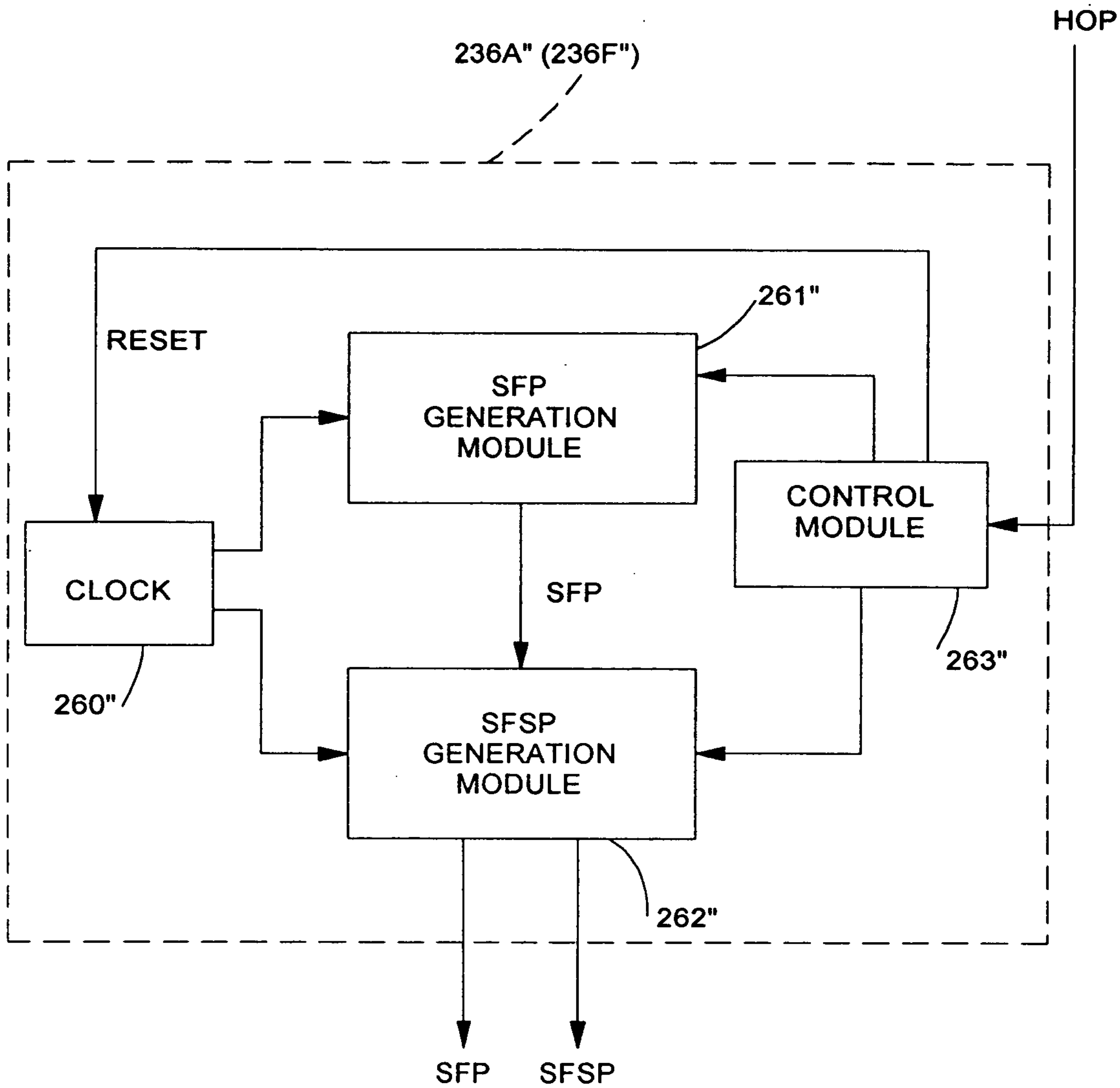

HOP
236A" (236F")
RESET
261"
SFP
GENERATION
MODULE
CONTROL
MODULE
CLOCK
SFP
263"
260"
SFSP
GENERATION
MODULE
262"
SFP
SFSP

FIG. 12B

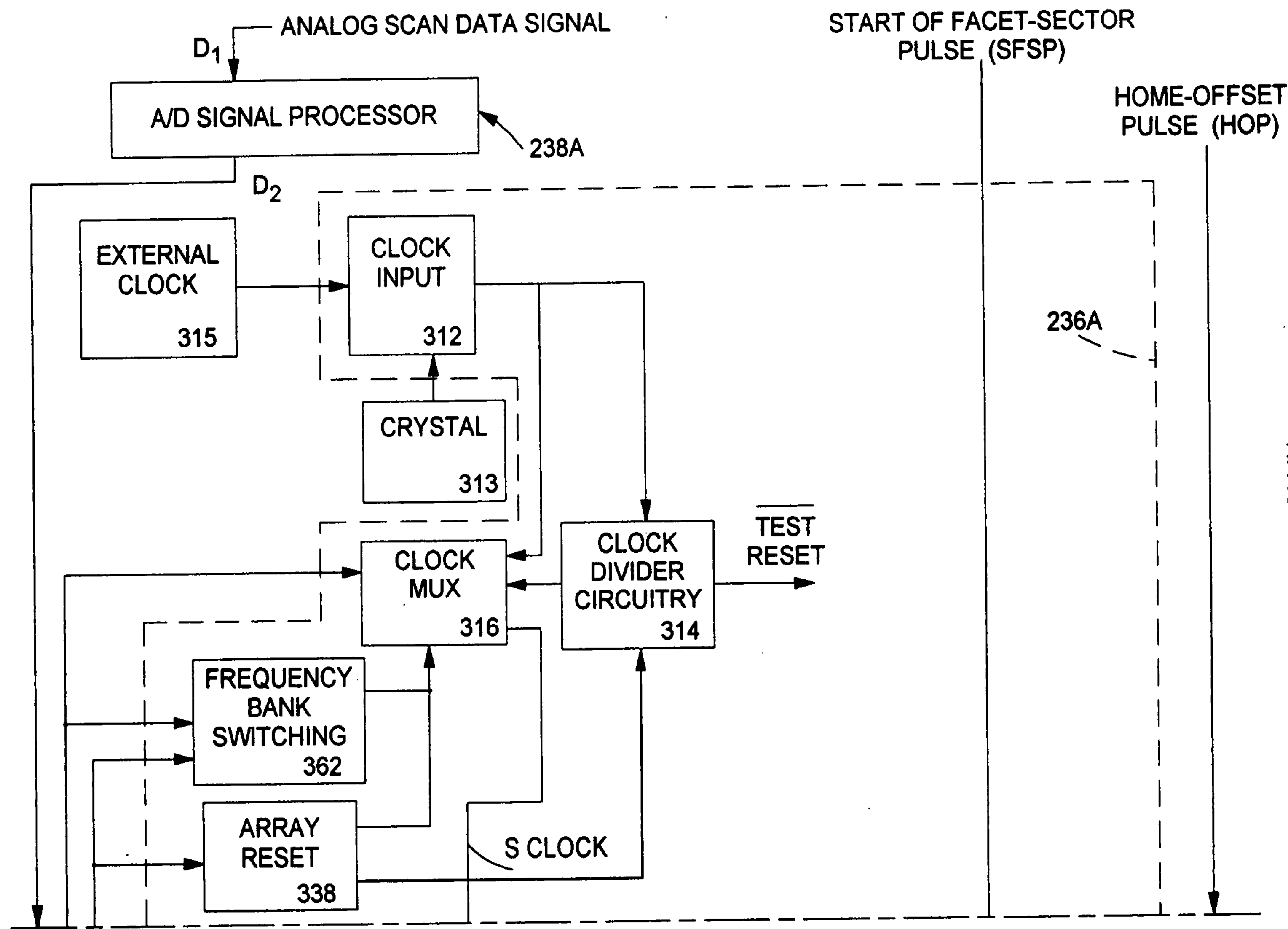
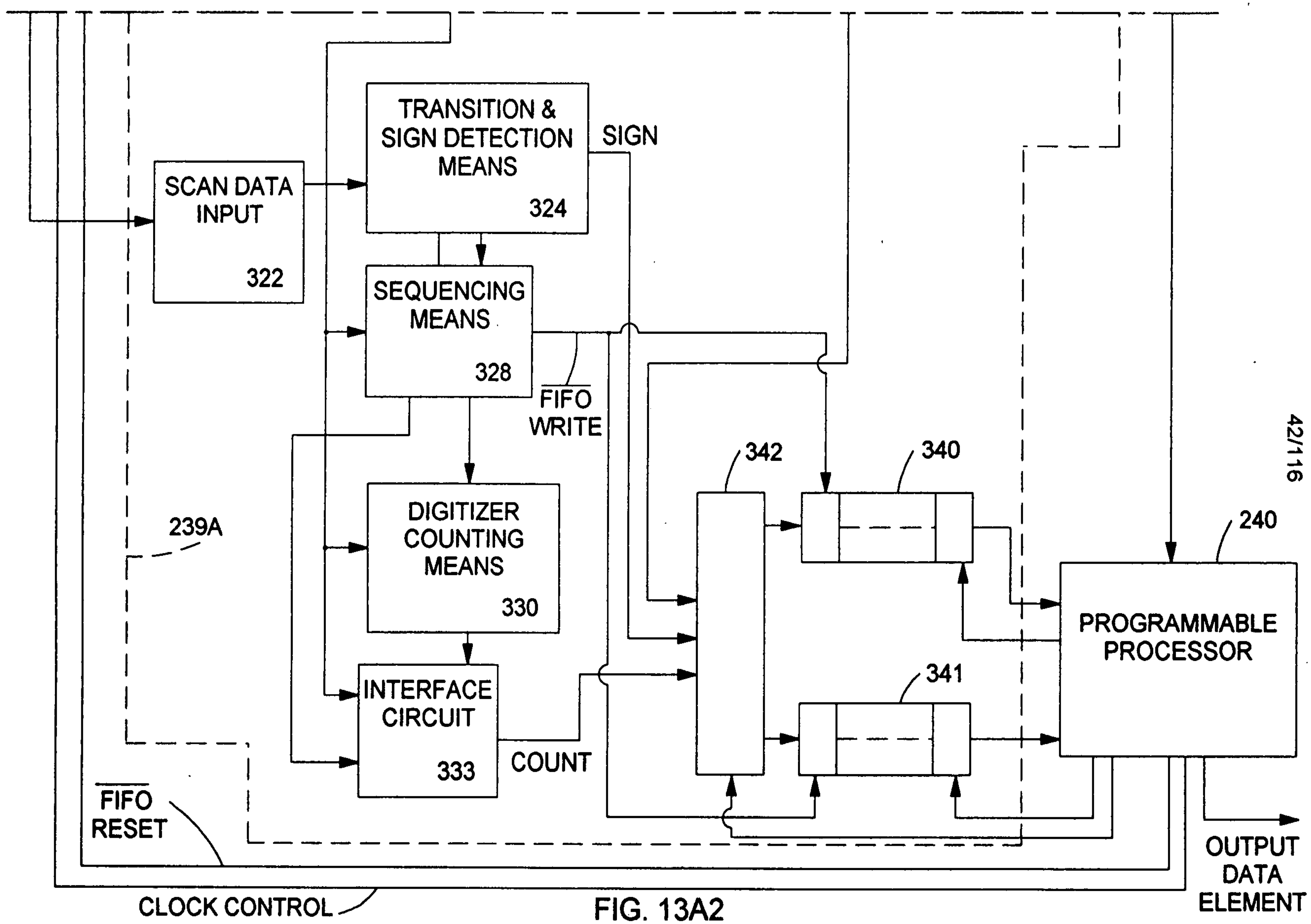

ANALOG SCAN DATA SIGNAL
D_1
A/D SIGNAL PROCESSOR
238A
D_2
START OF FACET-SECTOR PULSE (SFSP)
HOME-OFFSET PULSE (HOP)
EXTERNAL CLOCK 315
CLOCK INPUT 312
CRYSTAL 313
236A
CLOCK MUX 316
CLOCK DIVIDER CIRCUITRY 314
$\overline{\text{TEST RESET}}$
FREQUENCY BANK SWITCHING 362
ARRAY RESET 338
S CLOCK

FIG. 13A1



SCAN DATA INPUT
322
TRANSITION & SIGN DETECTION MEANS
324
SIGN
SEQUENCING MEANS
328
FIFO WRITE
DIGITIZER COUNTING MEANS
330
INTERFACE CIRCUIT
333
COUNT
342
340
341
PROGRAMMABLE PROCESSOR
240
239A
FIFO RESET
CLOCK CONTROL
OUTPUT DATA ELEMENT

FIG. 13A2

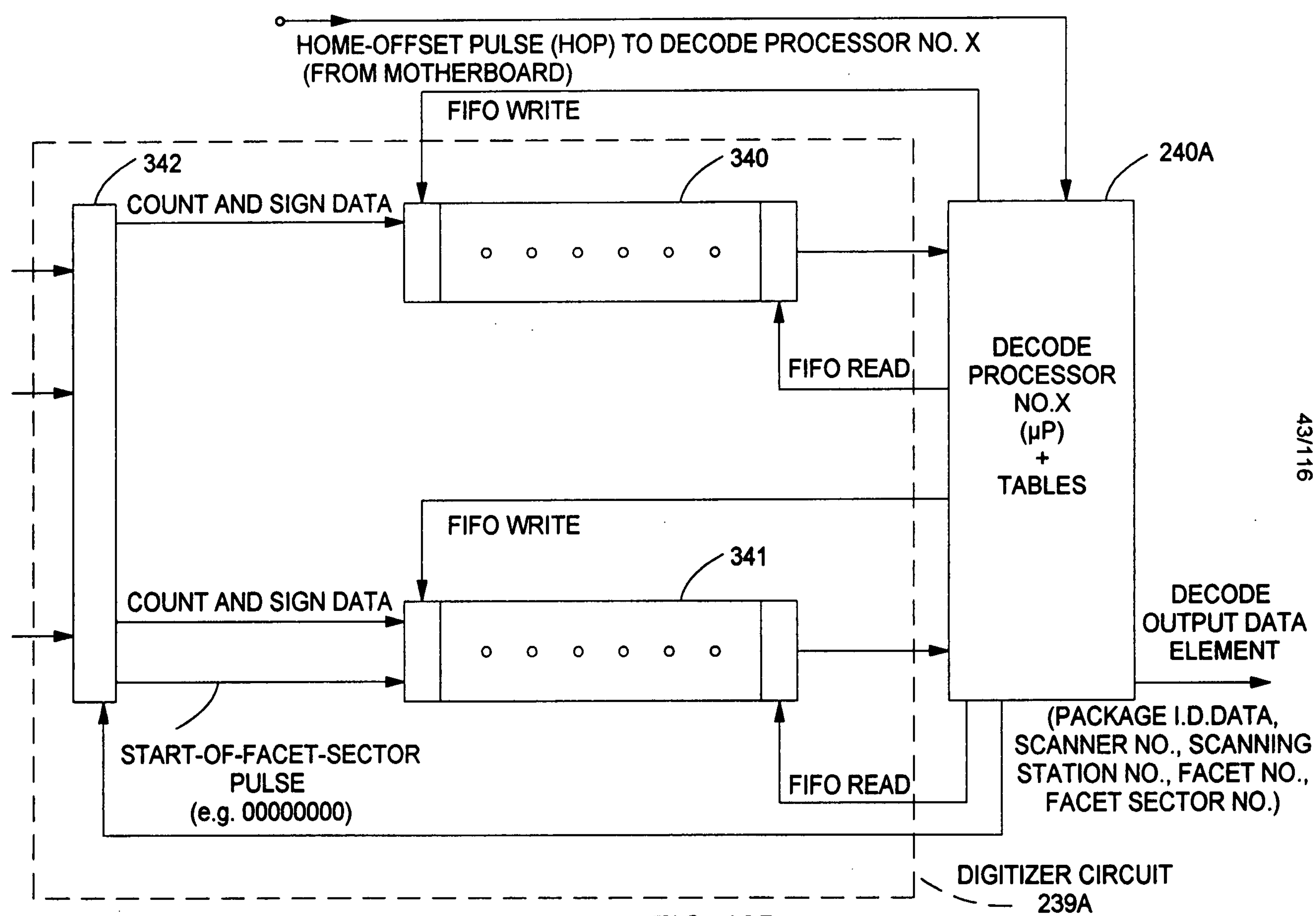

HOME-OFFSET PULSE (HOP) TO DECODE PROCESSOR NO. X
(FROM MOTHERBOARD)
FIFO WRITE
342
340
240A
COUNT AND SIGN DATA
FIFO READ
DECODE
PROCESSOR
NO.X
(μP)
+
TABLES
FIFO WRITE
341
COUNT AND SIGN DATA
DECODE
OUTPUT DATA
ELEMENT
(PACKAGE I.D.DATA,
SCANNER NO., SCANNING
STATION NO., FACET NO.,
FACET SECTOR NO.)
START-OF-FACET-SECTOR
PULSE
(e.g. 00000000)
FIFO READ
DIGITIZER CIRCUIT
239A

FIG. 13B

HOP GENERATION ALGORITHM

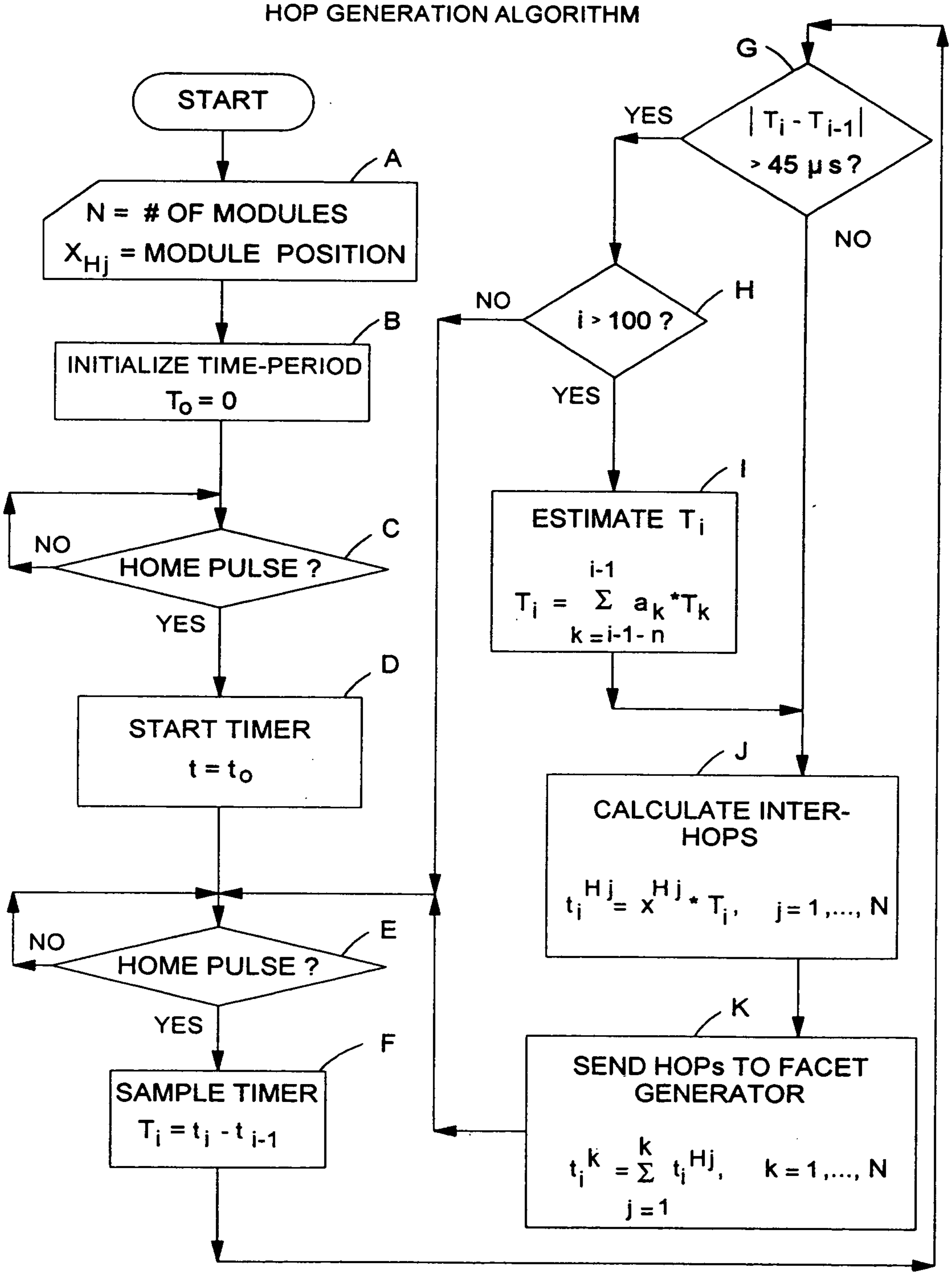


FIG. 14A

FACET / TICK GENERATION ALGORITHM

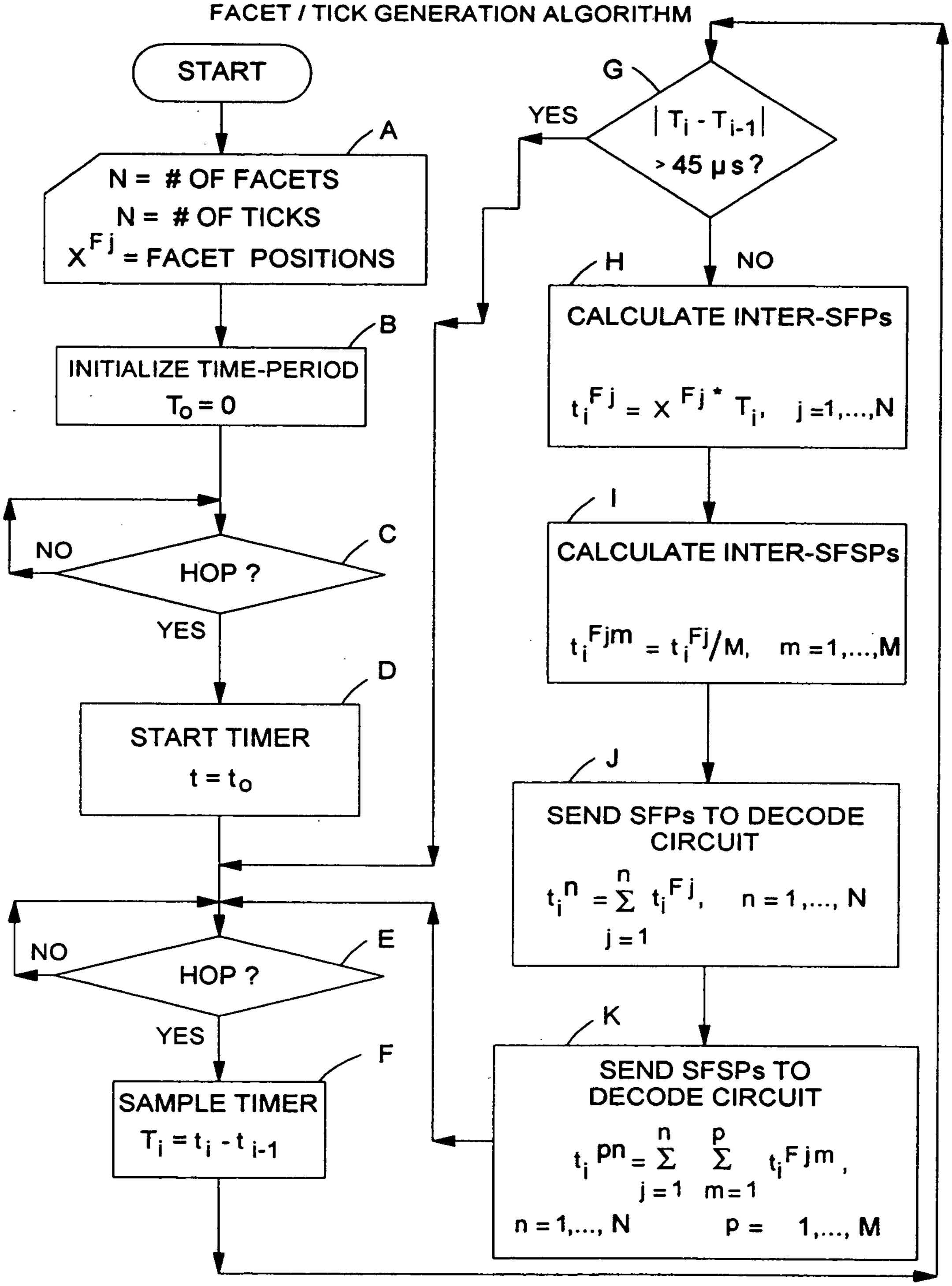


FIG. 14B

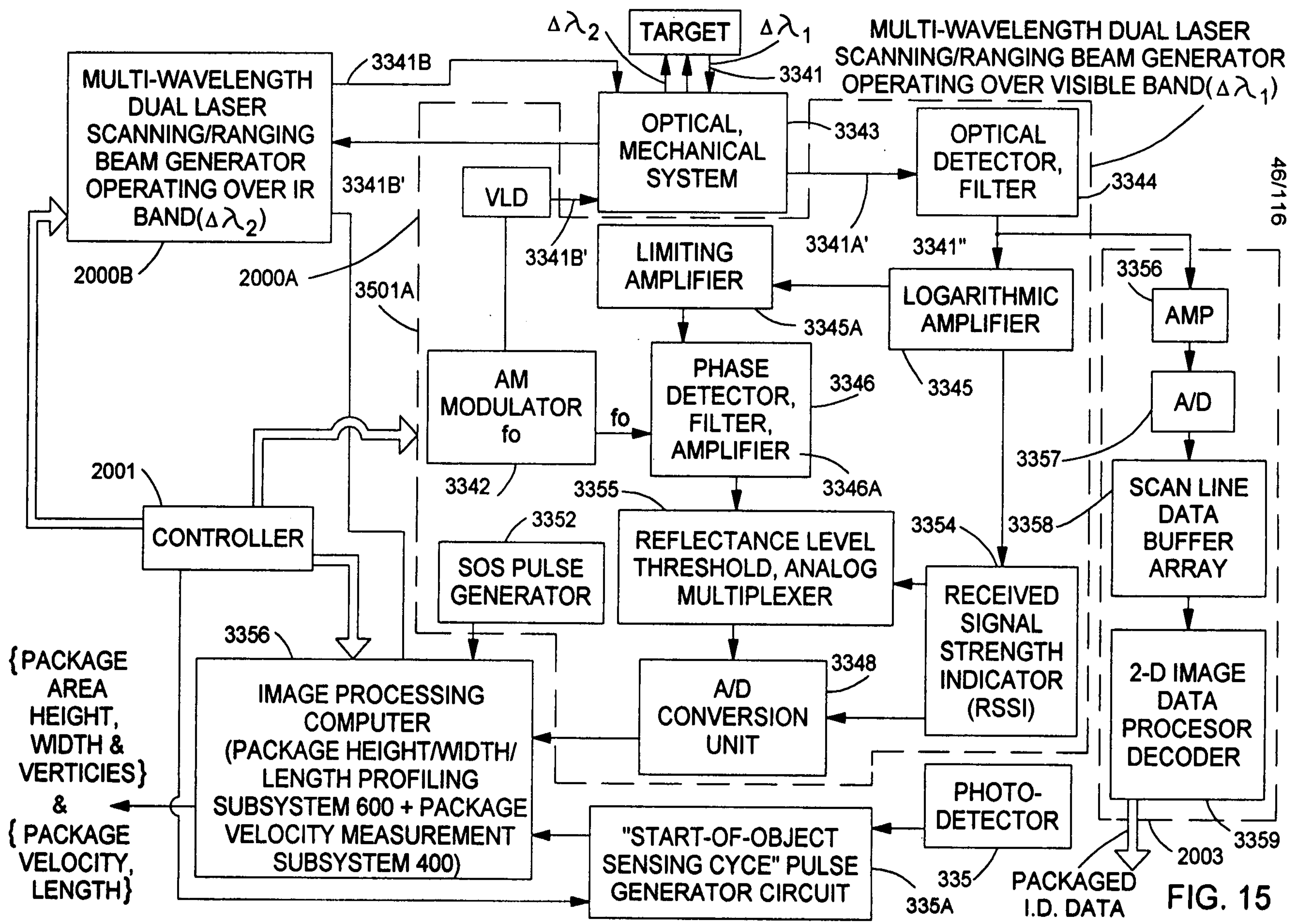

TARGET
Δλ2
Δλ1
3341
MULTI-WAVELENGTH DUAL LASER SCANNING/RANGING BEAM GENERATOR OPERATING OVER VISIBLE BAND(Δλ1)
MULTI-WAVELENGTH DUAL LASER SCANNING/RANGING BEAM GENERATOR OPERATING OVER IR BAND(Δλ2)
3341B
3341B'
2000B
2000A
3501A
OPTICAL, MECHANICAL SYSTEM
3343
OPTICAL DETECTOR, FILTER
3344
VLD
3341B'
3341A'
3341"
LIMITING AMPLIFIER
LOGARITHMIC AMPLIFIER
3345A
3345
3356
AMP
A/D
3357
AM MODULATOR fo
fo
PHASE DETECTOR, FILTER, AMPLIFIER
3346
3346A
3342
3355
2001
CONTROLLER
3352
SOS PULSE GENERATOR
REFLECTANCE LEVEL THRESHOLD, ANALOG MULTIPLEXER
3354
3358
RECEIVED SIGNAL STRENGTH INDICATOR (RSSI)
SCAN LINE DATA BUFFER ARRAY
3356
IMAGE PROCESSING COMPUTER (PACKAGE HEIGHT/WIDTH/ LENGTH PROFILING SUBSYSTEM 600 + PACKAGE VELOCITY MEASUREMENT SUBSYSTEM 400)
A/D CONVERSION UNIT
3348
2-D IMAGE DATA PROCESOR DECODER
{PACKAGE AREA HEIGHT, WIDTH & VERTICIES} & {PACKAGE VELOCITY, LENGTH}
PHOTO-DETECTOR
"START-OF-OBJECT SENSING CYCE" PULSE GENERATOR CIRCUIT
335
335A
2003
3359
PACKAGED I.D. DATA

FIG. 15

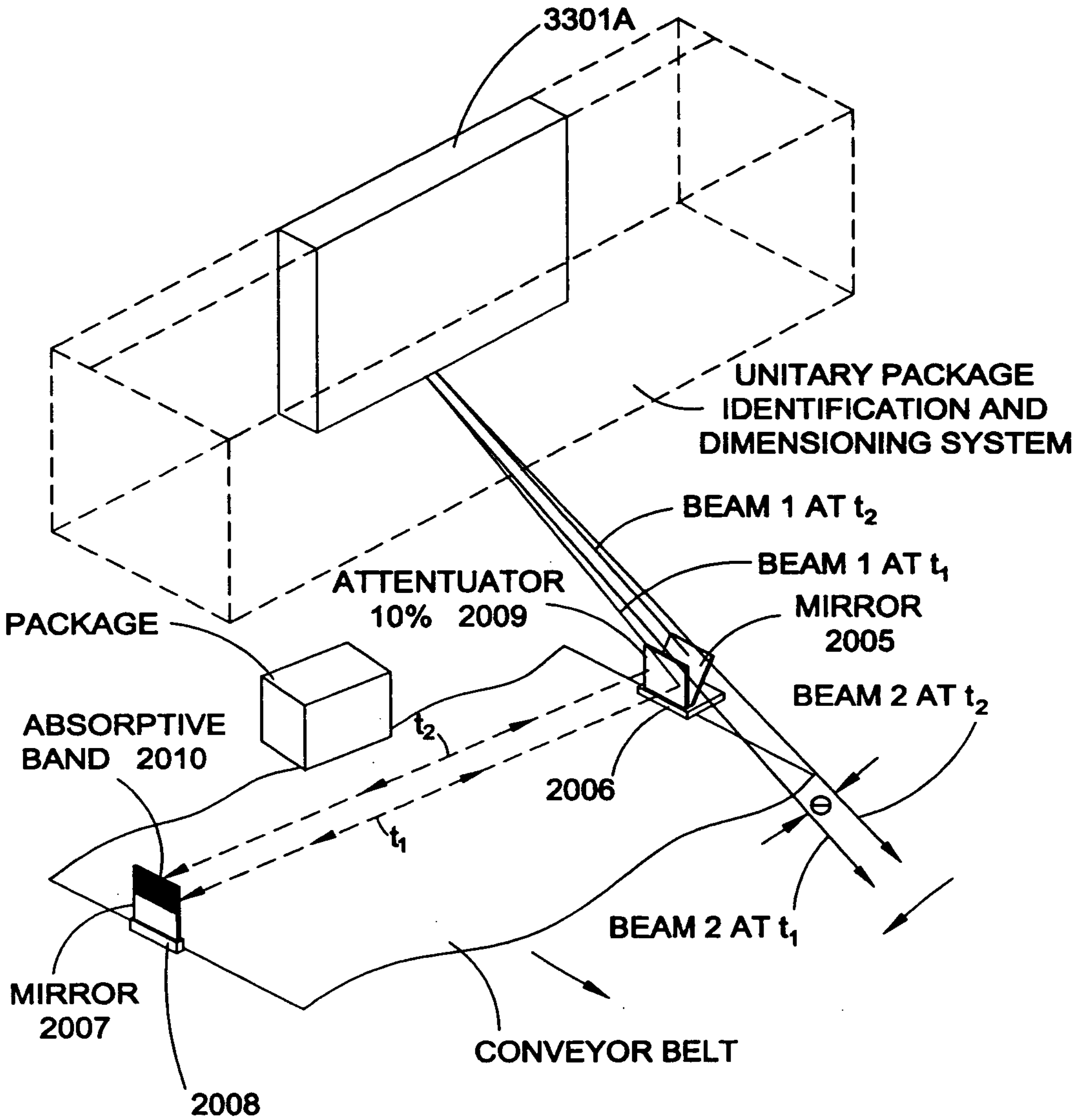
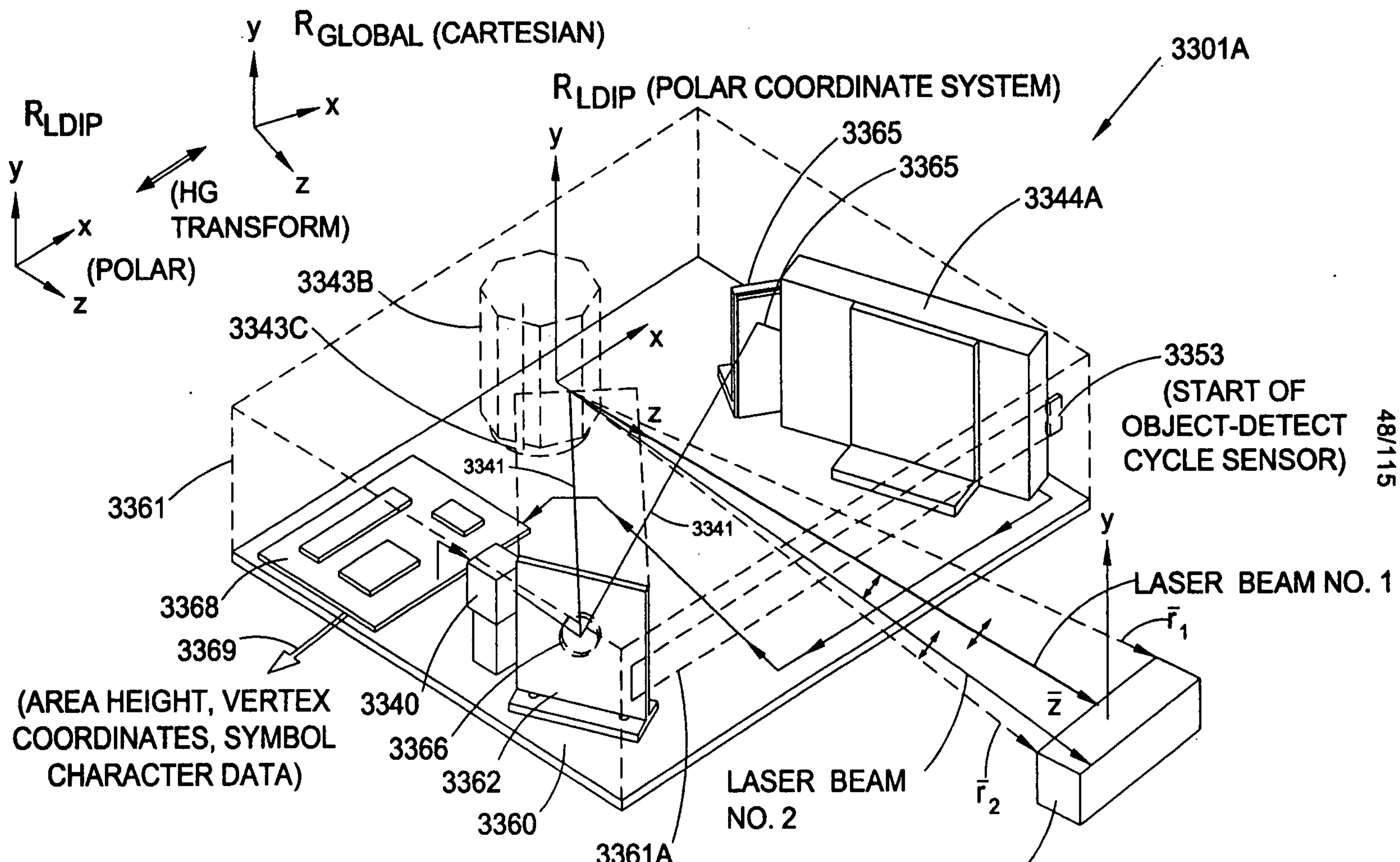

3301A
UNITARY PACKAGE IDENTIFICATION AND DIMENSIONING SYSTEM
BEAM 1 AT t_2
BEAM 1 AT t_1
ATTENTUATOR 10% 2009
MIRROR 2005
PACKAGE
BEAM 2 AT t_2
ABSORPTIVE BAND 2010
t_2
2006
Θ
t_1
BEAM 2 AT t_1
MIRROR 2007
CONVEYOR BELT
2008

FIG. 15A



$\bar{r}_1$ = RANGE MAGNITUDE, RANGE INTENSITY

FIG. 15B

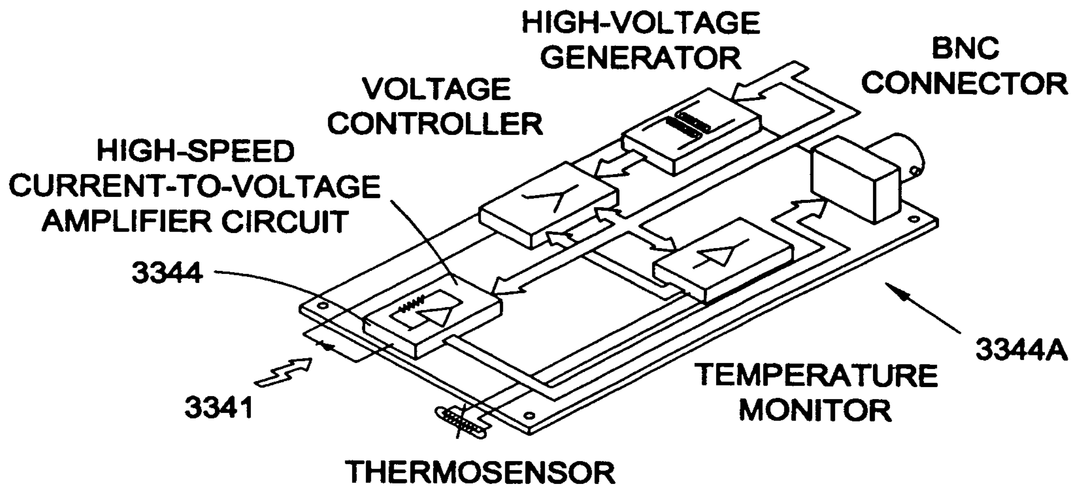


FIG. 15C

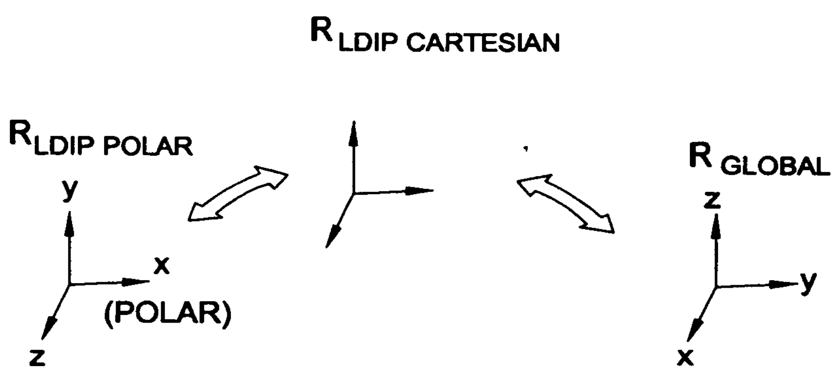


FIG. 15D

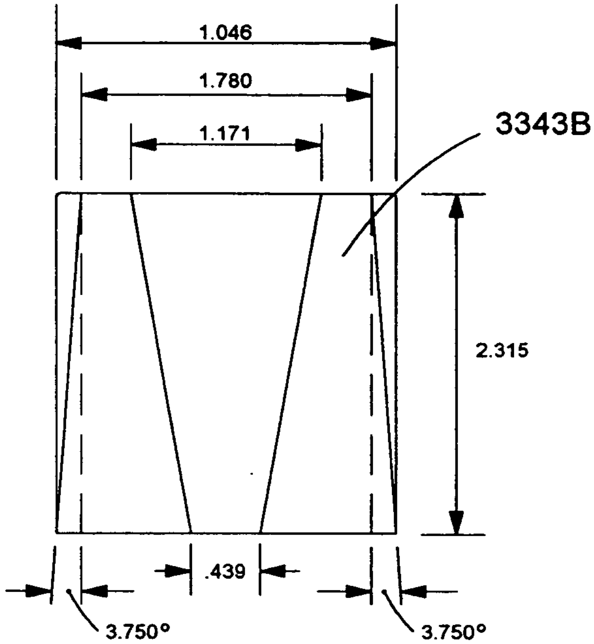


FIG. 15E1

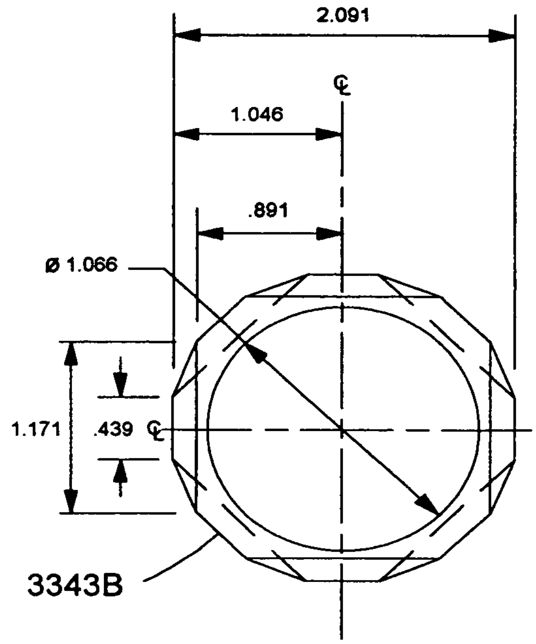


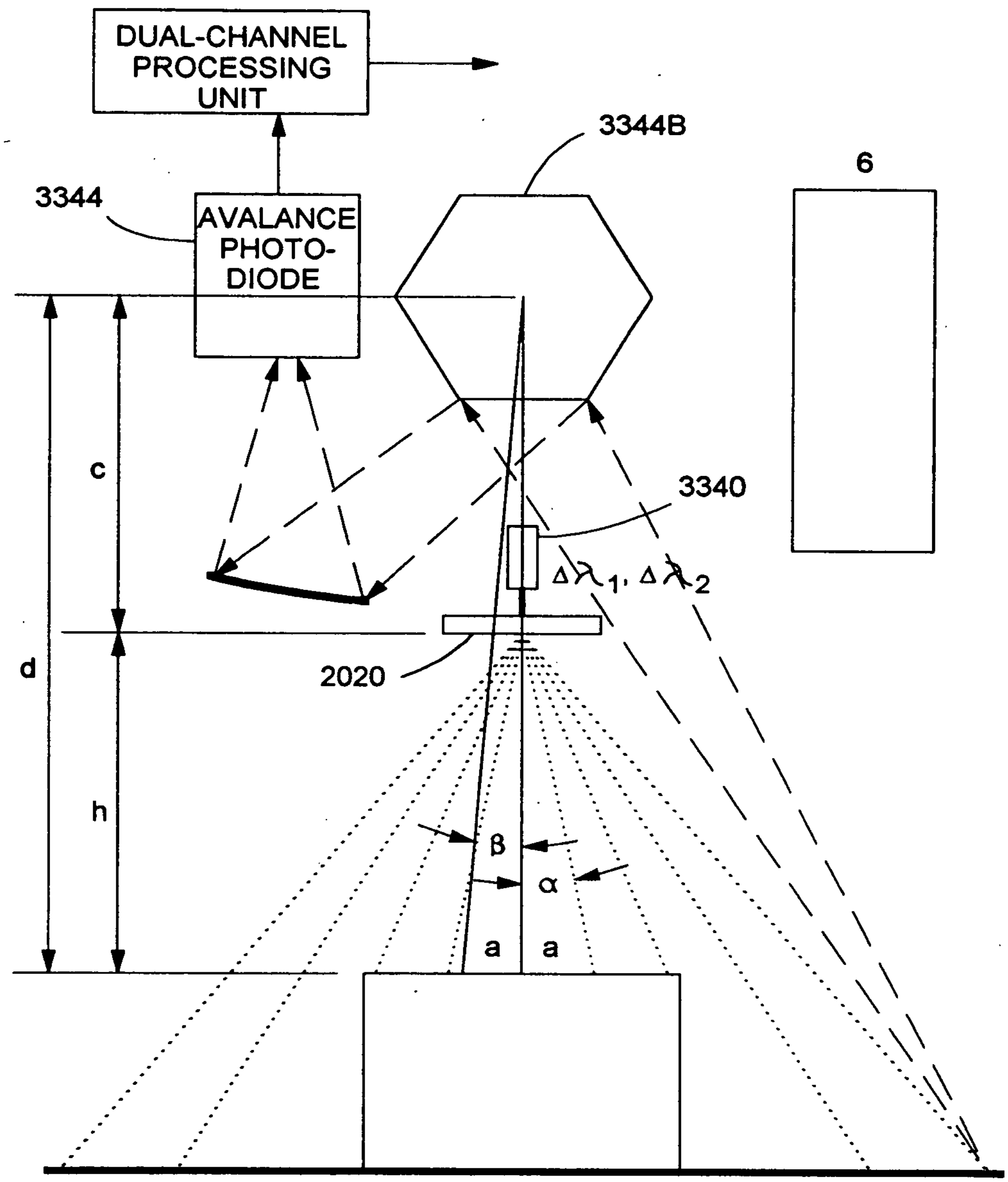
FIG. 15E2

FACE #	ANGLE (DEGREES)
1	3.75
2	-3.75
3	3.75
4	-3.75
5	3.75
6	-3.75
7	3.75
8	-3.75

FIG. 15E3

BEAM NO. 1	1	$\Delta\lambda_1$ $\Delta\lambda_2$
	3	
	5	
	7	
BEAM NO. 2	2	$\Delta\lambda_1$ $\Delta\lambda_2$
	4	
	6	
	8	

FIG. 15E4

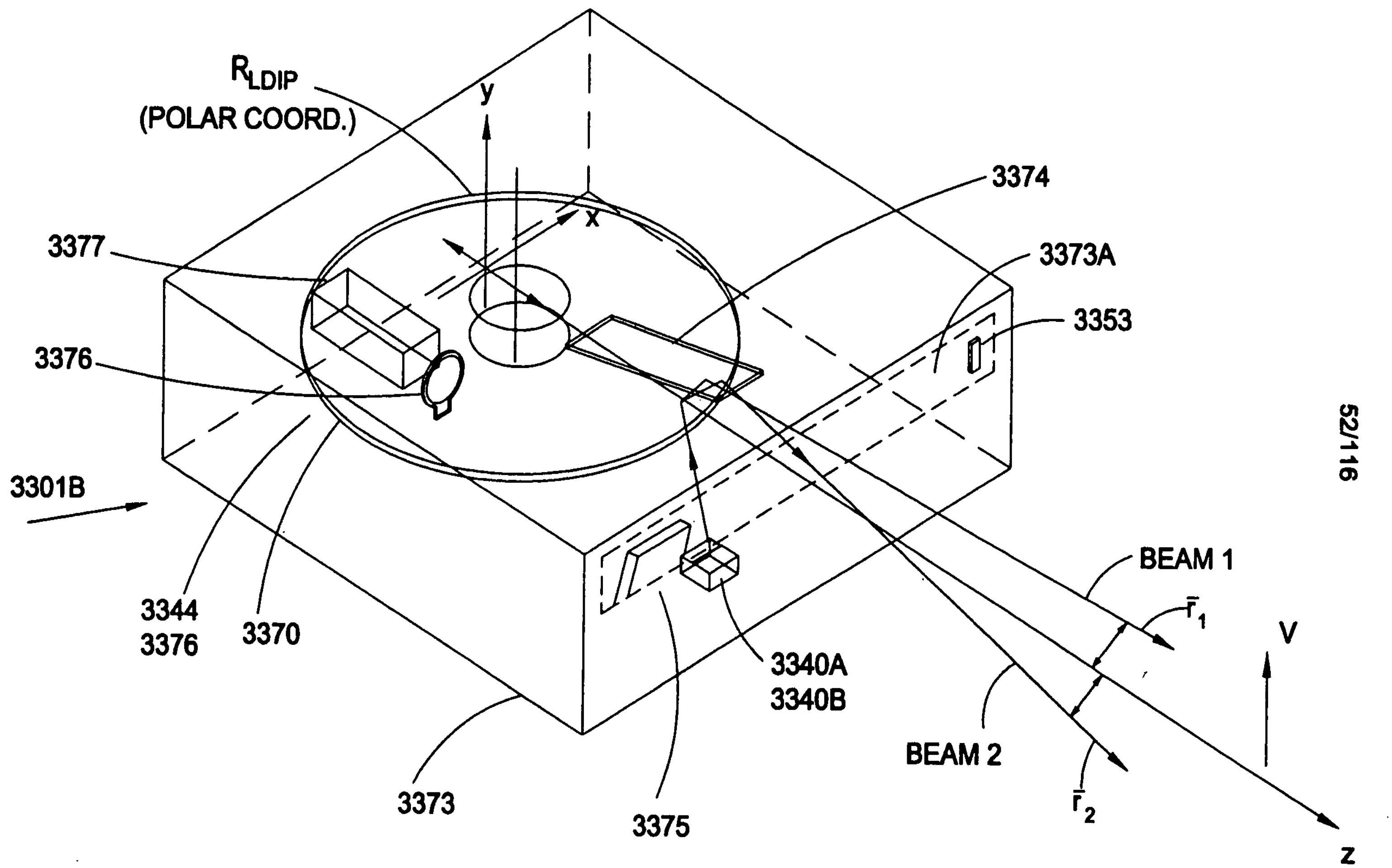


THE EQUATION FOR THE CALCULATION OF THE DISTANCE FROM THE DEVICE TO THE OBJECT:

$a = h \tan\alpha$, $a = d \tan\beta$, $d = h - c$

$h = (c \tan\beta)\,(\tan\alpha - \tan\beta)$

FIG. 15F



R_{LDIP}
(POLAR COORD.)
y
x
3374
3377
3373A
3353
3376
3301B
3344
3376
3370
3373
3375
3340A
3340B
BEAM 1
BEAM 2
$\bar{r}_1$
$\bar{r}_2$
V
z

FIG. 15G

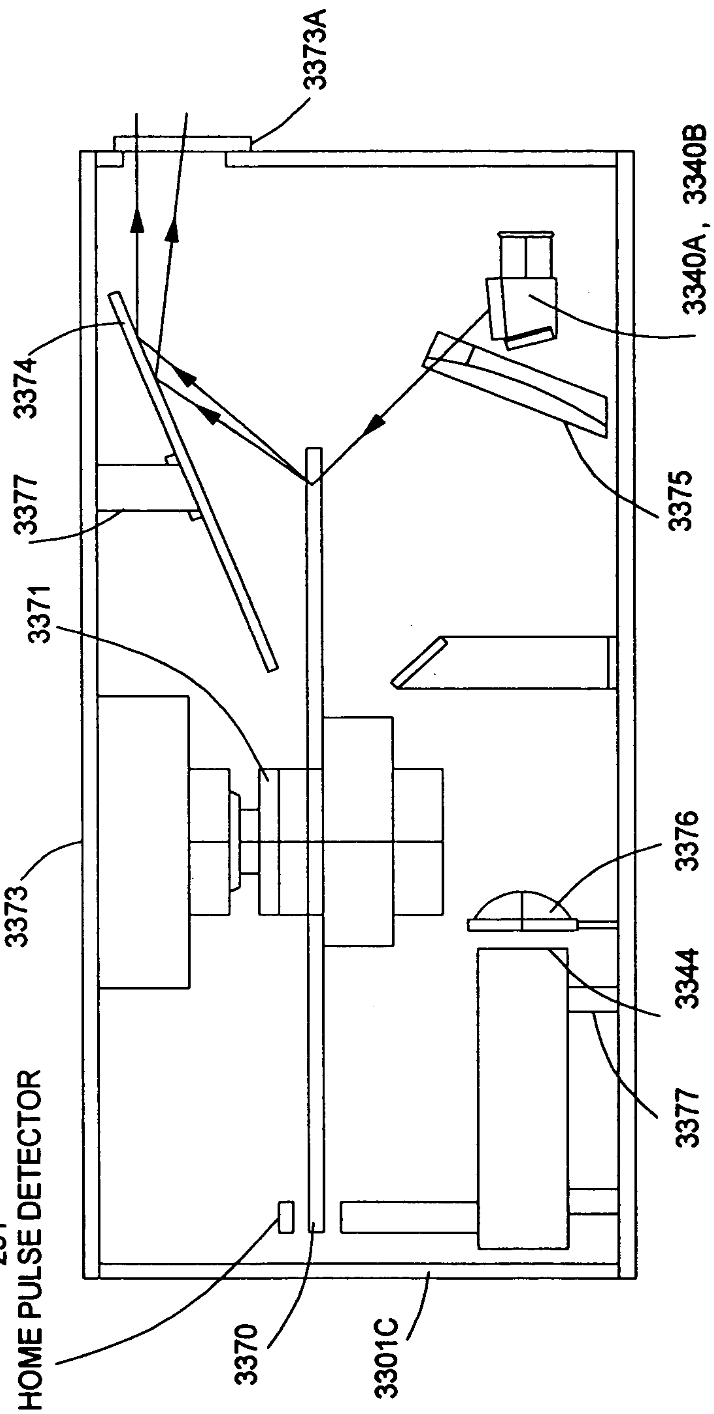

3373A
3340A , 3340B
3374
3377
3375
3371
3373
3376
3344
3377
251
HOME PULSE DETECTOR
3370
3301C

FIG. 15H

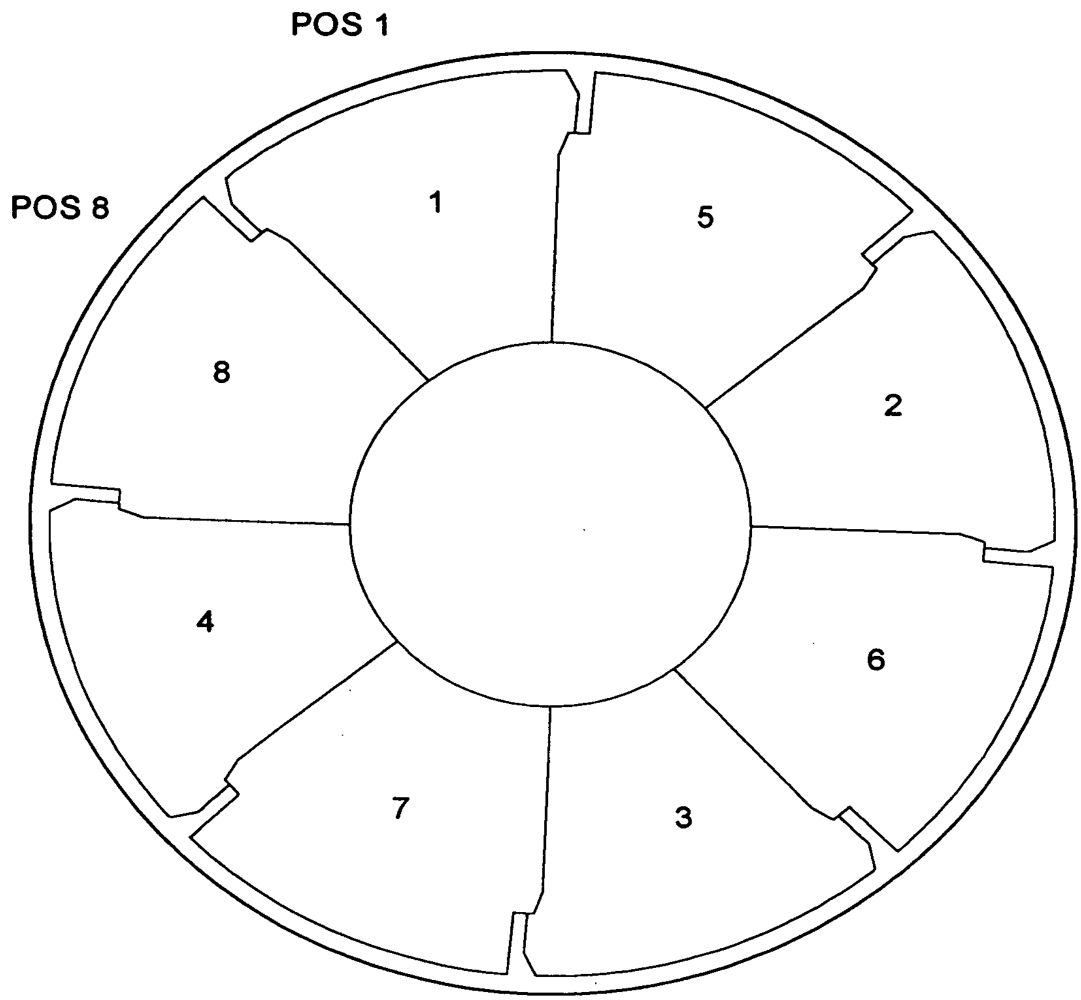


FIG. 15I

ROTATIONAL SPEED OF DISK (RPM)								
						658	nm	
FACET	DIFFRACTION FOCAL LENGTH (INCHES)	GEOMETRICAL FOCAL LENGTH (INCHES)	ANGLE A (DEGREES)	ANGLE B (DEGREES)	ANGLE OF DIFFRACTION (DEGREES)	ANGLE OF BEAM FROM VERTICAL (DEGREES)	SCAN ANGLE (DEGREES)	SCAN MULTI. FACTOR (m)
1	65.41	5000.00	45.9	53.00	37.00	5.00	54.93	1.29
2	65.41	5000.00	45.9	53.00	37.00	5.00	54.93	1.29
3	65.41	5000.00	45.9	53.00	37.00	5.00	54.93	1.29
4	65.41	5000.00	45.9	53.00	37.00	5.00	54.93	1.29
5	65.41	5000.00	45.9	48.00	42.00	10.00	54.93	1.36
6	65.41	5000.00	45.9	48.00	42.00	10.00	54.93	1.36
7	65.41	5000.00	45.9	48.00	42.00	10.00	54.93	1.36
8	65.41	5000.00	45.9	48.00	42.00	10.00	54.93	1.36

FIG. 15JI

ROTATION ANGLE (DEGREES)	ACCOUNTING FOR DEAD TIME FOR LASER BEAM	LIGHT COLLECTION FACTOR	MAXMIMUM COLLECTION AREA (IGNORING NOTCH) (SQ. IN.)	DESIGN COLLECTION AREA (INCLUDES NOTCH LOSS OF 0.15 SQ. INCHES)	BEAM SPEED AT CENTER OF SCAN LINE (INCHES /SEC)	BEAM SPEED AT MAX. DEPTH OF FIELD (INCHES /SEC)	BEAM SPEED AT MIN. DEPTH OF FIELD (INCHES /SEC)	BEAM SKEW ANGLE (DEGREES)
42.30	44.30	1.00	5.29	5.30	46251	51021	41302	0
42.30	44.30	1.00	5.29	5.30	46251	51021	41302	0
42.30	44.30	1.00	5.29	5.30	46251	51021	41302	0
42.30	44.30	1.00	5.29	5.30	46251	51021	41302	0
39.82	41.82	1.19	6.30	6.28	48649	53855	43443	0
39.82	41.82	1.19	6.30	6.28	48649	53855	43443	0
39.82	41.82	1.19	6.30	6.28	48649	53855	43443	0
39.82	41.82	1.19	6.30	6.28	48649	53855	43443	0

FIG. 15J2

BEAM NO.	FACET NOS.	
1	1	$\Delta\lambda_1$, $\Delta\lambda_2$
	2	
	3	
	4	
2	5	$\Delta\lambda_1$, $\Delta\lambda_2$
	6	
	7	
	8	

FIG. 15K

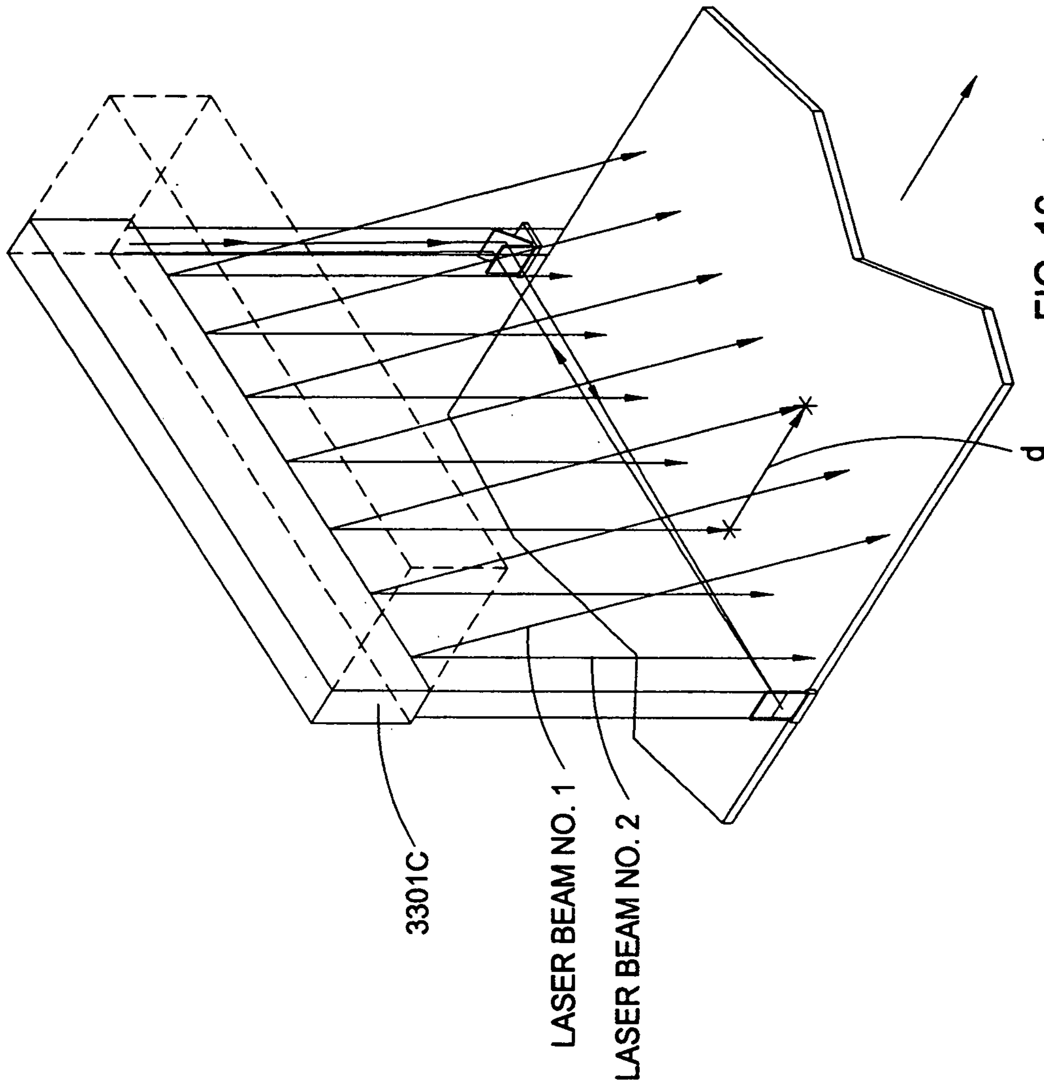


FIG. 16

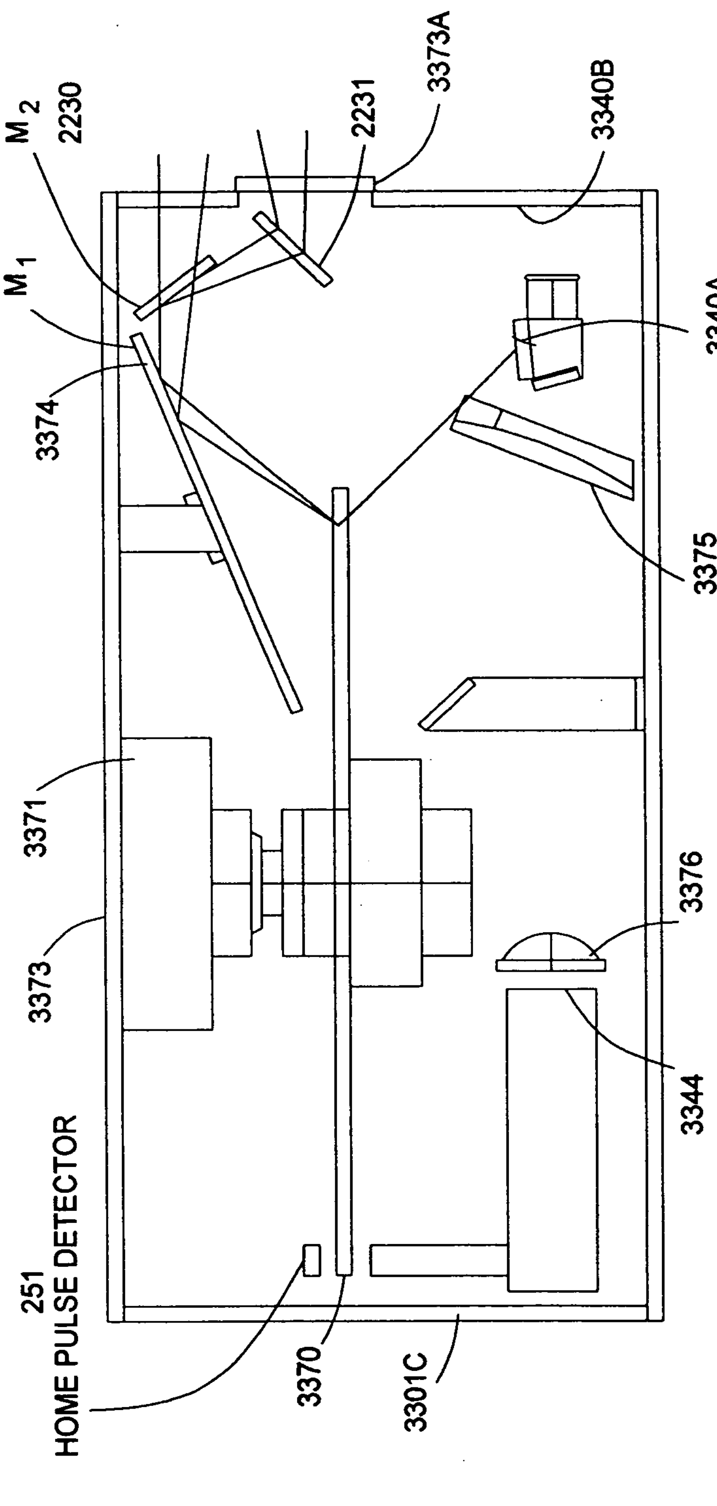


FIG. 16A

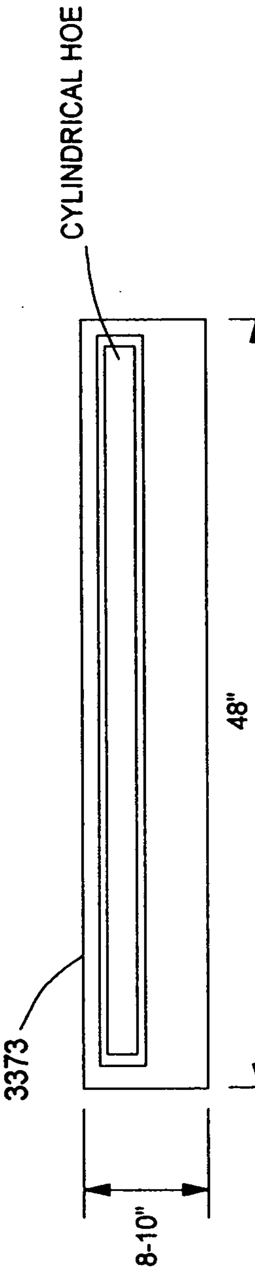


FIG. 16B

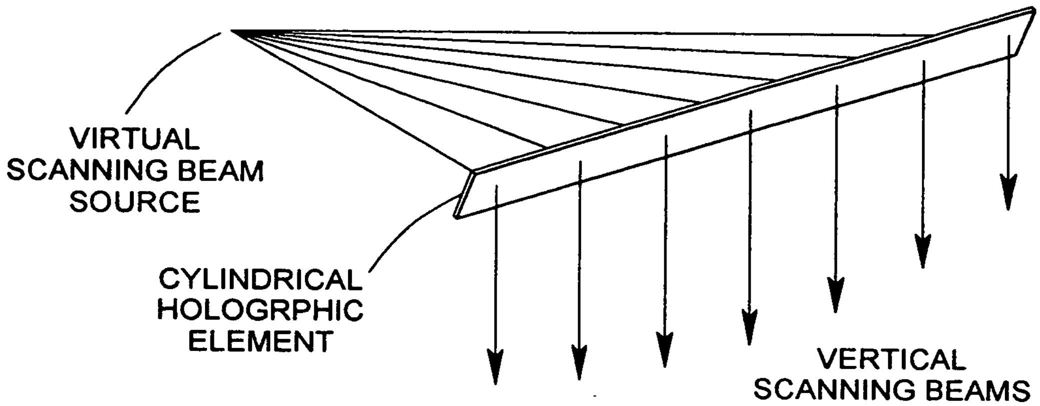


FIG. 16D

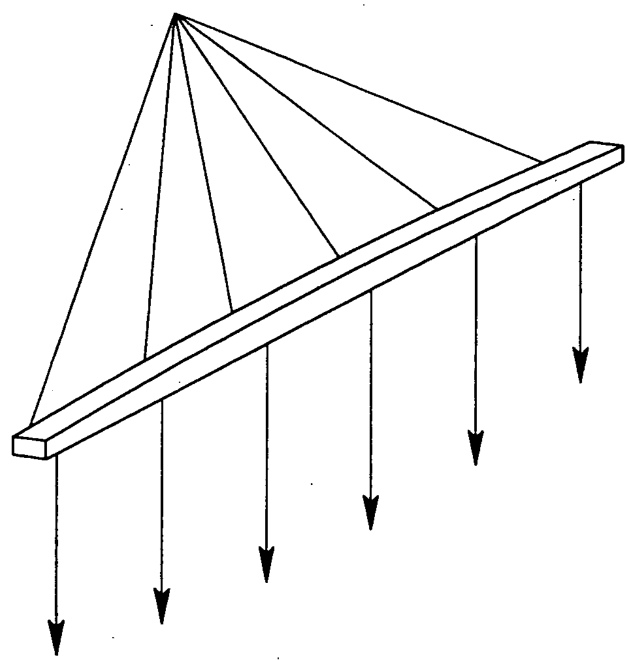
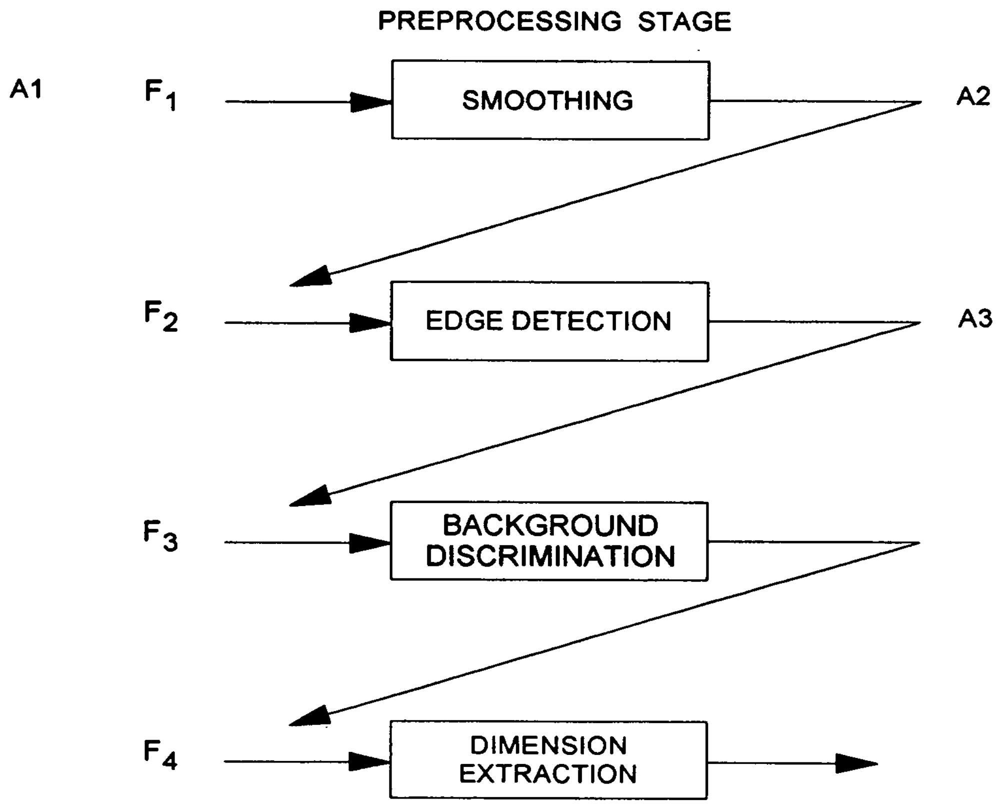


FIG. 16E

HEIGHT/WIDTH/PROFILING
PACKAGE DIMENSIONING SUBSYSTEM

(600) FIGS. 17 - 29B



F_1 = RAW IMAGE

F_2 = SMOOTH IMAGE

F_3 = EDGE IMAGE

F_4 = OBJECT IMAGE

F_5 = AREA HEIGHT, AND CORNER COORDINATES

FIG. 17

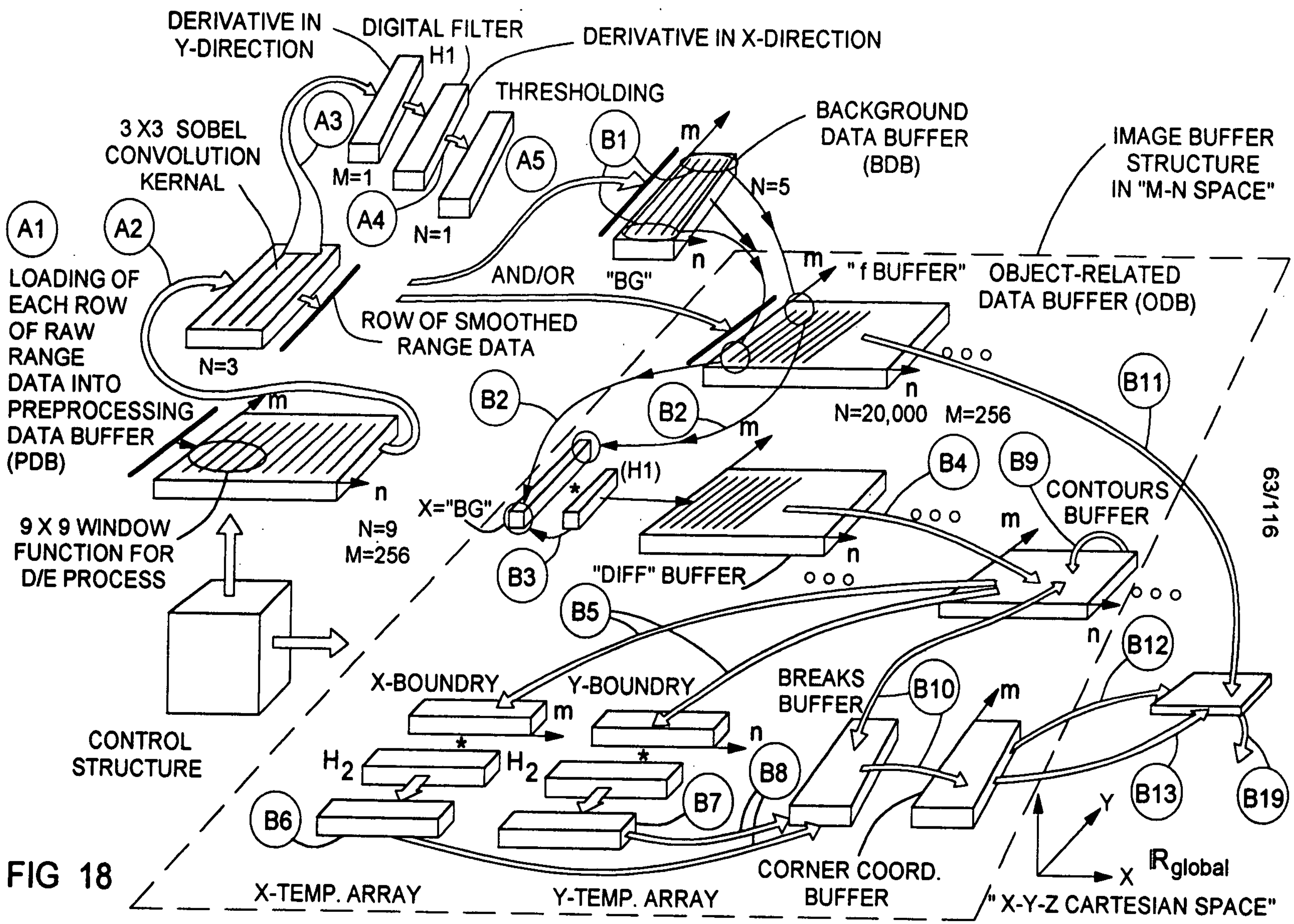

DERIVATIVE IN Y-DIRECTION
DIGITAL FILTER
H1
DERIVATIVE IN X-DIRECTION
THRESHOLDING
3 X3 SOBEL CONVOLUTION KERNAL
A1
A2
A3
A4
A5
M=1
N=1
LOADING OF EACH ROW OF RAW RANGE DATA INTO PREPROCESSING DATA BUFFER (PDB)
N=3
ROW OF SMOOTHED RANGE DATA
AND/OR
"BG"
B1
BACKGROUND DATA BUFFER (BDB)
N=5
IMAGE BUFFER STRUCTURE IN "M-N SPACE"
" f BUFFER"
OBJECT-RELATED DATA BUFFER (ODB)
N=20,000 M=256
B2
B2
(H1)
X="BG"
B3
9 X 9 WINDOW FUNCTION FOR D/E PROCESS
N=9
M=256
"DIFF" BUFFER
B4
B9
CONTOURS BUFFER
B11
B5
CONTROL STRUCTURE
X-BOUNDRY
Y-BOUNDRY
BREAKS BUFFER
B10
B12
H2
H2
B6
B7
B8
B13
B19
CORNER COORD. BUFFER
X-TEMP. ARRAY
Y-TEMP. ARRAY
" X-Y-Z CARTESIAN SPACE"
Y
X
$\mathbb{R}_{global}$

FIG 18

CONTROL STRUCTURES

INPUT OF OPERATOR PARAMETERS AND INITIALIZATIONS

```
FOR z := 1 TO n  DO
     READ ROW  z OF  ƒ  INTO THE IMAGE  ROW STORE
     BUF(1...M, IND (z));
FOR y :=  k + 1  to N - k  DO BEGIN
          FOR x :=k + 1 TO M - k  DO BEGIN
                   FOR z := 1 TO a DO
                              F (z) :=BUF(x + xind(z), ind(k + 1 + yind(z))):
```

PROCESSING OF THE PICTURE WINDOW F(ƒ,(x,y)) WITH A SPECIFIC OPERATOR KERNEL ARGUMENTS: F(z), WITH 1 ≤ z ≤ a, OR F(i,j,), WITH -k ≤ i, j ≤ k)

RESULT: GRAY VALUE v

```
⊕                  IF (PARSEQ = 0) THEN
                        BUFOUT (x) := v
⊕                  ELSE  BUF (x, IND (k+1)) := v
                   END{for};
⊕         IF (PARSEQ = 0) THEN
                   WRITE ROW BUFFER STORE BUFOUT(1...M) INTO
                   ROW y OF THE RESULTANT IMAGE FILE OUT
⊕         ELSE
⊕                  WRITE IMAGE ROW STORE BUF(1...M, IND(K+ 1)) INTO
⊕                  ROW y OF THE RESULTANT IMAGE FILE OUT;
          IF  (y   N - k)  THEN BEGIN
                   READ ROW y + k + 1 OF THE INPUT IMAGE FILE INTO
                   THE IMAGE ROW STORE BUF(1...M, IND(1));
                   LINK := IND(1);
                   FOR z := 1 TO n - 1 DO IND(z) := IND(z +1)
                   IND(n) := LINK
                   END {if}
          END {for}
```

CONTROL STRUCTURE FOR THE COMPUTATION OF LOCAL OPERATORS, USING ROW-WISE BUFFERING, THE CENTERED ij-COORDINATE SYSTEM, AND THE SPATIAL ARRANGEMENT FOR THE WINDOW CONTENT IF THE ONE-DIMENSIONAL ARRAY F(z) IS USED. PROGRAM LINES LABLED WITH ⊕ ARE SUPERFLUOUS IF A PARALLEL OPERATOR HAS TO BE IMPLEMENTED

FIG. 19

A

STEP A1 INVOLVES CAPTURING LINES (ROWS) OF DIGITIZED RANGE DATA PRODUCED BY THE LASER SCANNING/RANGING UNIT DURING EACH SWEEP OF THE AMPLITUDE MODULATED LASER BEAM ACROSS THE WIDTH OF THE CONVEYER BELT. EACH ROW OF RAW RANGE DATA HAS A PREDETERMINED NUMBER OF RANGE VALUE SAMPLES (E.G. M=256) TAKEN DURING EACH SCAN ACROSS THE CONVEYOR BELT. EACH SUCH RANGE DATA SAMPLE REPRESENTS THE MAGNITUDE OF THE POSITION VECTOR POINTING TO THE CORRESPONDING SAMPLE SAMPLE POINT ON THE SCANNED PACKAGE, REFERENCED WITH RESPECT TO A POLAR-TYPE COORDINATE SYSTEM SYMBOLICALY EMBEDDED WITHIN THE LADAR-BASED IMAGING AND DIMENSIONING SUBSYSTEM. STEP A1 ALSO INVOLVES LOADING A PREDETERMINED NUMBER OFRAW RANGE DATA SAMPLES INTO A FIFO-TYPE PREPROCESSING DATA BUFFER (e.g. M=9) FOR BUFFERING 9 ROWS OF RANGE DATA AT ANY INSTANT OF TIME.

B

STEP A2 INVOLVES USING, AT EACH PROCESSING CYCLE AND SYNCHRONIZED WITH THE CAPTURE OF EACH NEW ROW OF RAW RANGE DATA, A 2-D (9X9) WINDOW FUNCTION EMBEDDED INTO A GENERAL CONTROL STRUCTURE (e.g. PIXEL PROGRAM LOOP), TO SMOOTH EACH LINE (OR ROW) OF RAW RANGE DATA BUFFERED IN THE PROCESSING DATA BUFFER USING DILUTION AND EROSION (D/E) PROCESS BASED ON NON-LINEAR TYPE MIN/MAX METHODS. THE OUTPUT FROM THIS NON-LINEAR OPERATION IS A SINGLE ROW OF SMOOTH RANGE DATA OF LENGTH M=256 WHICH IS INPUT TO A THREE ROW FIFO BUFFER, AS SHOWN IN FIG. 44G.

C

STEP 3A INVOLVES USING, AT EACH PROCESSING CYCLE, A 2-D (3X3) CONVOLUTION KERNEL BASED ON THE SOBEL OPERATOR, AND EMBEDDED INTO A GENERAL CONTROL STRUCTURE (e.g. PIXEL PROGRAM LOOP), TO EDGE-DETECT EACH BUFFERED ROW OF SMOOTH EDGE DATA OF LENGTH M=256 WHICH IS INPUT TO A FIRST ONE ROW (N=1) FIFO BUFFER AS SHOWN IN FIG. 44G. THE OUTPUT ROW OF "EDGE DETECTED" RANGE DATA REPRESENTS THE FIRST SPATIAL DERIVATIVE A OF THE BUFFERED ROWS OF RANGE DATA ALONG THE n DIRECTION OF THE N=9 FIFO (CORRESPONDING TO THE FIRST SPATIAL DERIVITIVE OF THE RANGE DATA CAPTURED ALONG THE Y DIRECTION OF THE CONVEYER BELT.

A

FIG. 20A

A

D

STEP A4 INVOLVES USING, AT EACH PROCESSING CYCLE, A 7-TAP FIR-TYPE DIGITAL FILTER (H1) TO COMPUTE THE FIRST SPATIAL DERIVATIVE OF THE BUFFERED ROW OF EDGE-DETECTED RANGE DATA ALONG THE m DIRECTION OF THE N=9 FIFO (CORRESPONDING TO THE FIRST SPATIAL DERIVATIVE OR THE RANGE DATA CAPTURED ALONG THE x DIRECTION OF THE CONVEYOR BELT). THE OUTPUT OF THIS OPERATION IS STORED IN A SECOND ONE ROW (N=1) FIFO, AS SHOWN IN FIG. 44G.

E

STEP A5 INVOLVES ANALYZING, AT EACH PROCESSING CYCLE, THE EDGE -DETECTED DERIVATIVE STORED IN THE SECOND ONE ROW FIFO IN ORDER TO (1) FIND THE MAXIMUM VALUE THEREOF, AND THEN (2) COMPARE THE MAXIMUM DERIVATIVE VALUE TO A PREDETERMINED THRESHOLD VALUE. IF ANY OF THE MAXIMUM FIRST DERIVATIVE VALUES IS LARGER THAN THE PREDETERMINED THRESHOLD VALUE, THEN THE UNLOADED ROW OF SMOOTHED RANGE DATA (FROM OUTPUT PORT OF THE THREE ROW FIFO) IS LABELLED AS CONTAINING OBJECT DATA, AND IS LOADED INTO THE INPUT PORT OF THE FIFO-TYPE OBJECT-RELATED DATA BUFFER (ODB), ALSO REFERRED TO AS THE "f" BUFFER, FOR FUTURE USE. OTHERWISE, THE UNLOADED ROW OF SMOOTHED RANGE DATA FROM THE THREE ROW FIFO IS LABELED AS CONTAINING BACKGROUND DATA AND IS LOADED INTO THE INPUT PORT OF THE FIFO-TYPE BACKGROUND DATA BUFFER (BDB), AND POSSIBLY THE ODB, FOR FUTURE USE.

F

STEP B1: AT EACH PROCESSING CYCLE, AND FOR EACH COLUMN POSITION IN THE ROWS BACKGROUND DATA IN THE BDB (REFERENCED BY INDEX m), COMPUTE THE "MEDIAN VALUE" BASED ON THE CURRENT ROWS OF BACKGROUND DATA BUFFERED THEREIN.

G

STEP B2: AT EACH PROCESSING CYCLE, AND FOR EACH ROW OF OBJECT-RELATED DATA IN THE ODB, SUBTRACT THE PRECOMPUTED MEDIAN VALUE (BG) FROM THE CORRESPONDING RANGE VALUE (f=X), TO PRODUCE A DIFFERENCE VALUE (X-BG) FOR EACH OF THE 256 COLUMN POSITIONS IN THE CORRESPONDING ROW OF OBJECT-RELATED DATA BEING BUFFERED IN THE ODB (ALSO INDICATED AS THE "f BUFFER"), THEREBY PRODUCING A VERTICAL FIRST DISCRETE DERIVATIVE THEREOF (HAVING A COLUMN LENGTH M=256).

B

FIG. 20B

A

H

STEP B3: AT EACH PROCESSING CYCLE, SMOOTH THE COMPUTED VERTICAL FIRST DISCRETE DERIVATIVE BY CONVOLVING THE SAME WITH A 5-TAP FIR SMOOTHING FILTER AND TRUNCATING THE RESULTANT ROW OF SMOOTHED DISCRETE DERIVATIVE DATA TO LENGTH M=256, AND THEREAFTER LOAD THE ROW OF SMOOTHED DISCRETE DERIVATIVE DATA IN THE "DIFF" (i.e. DERIVATIVE) DATA BUFFER HAVING m=256 COLUMNS AND n=10,000 OR MORE ROWS (AS REQUIRED BY THE COLLECTED RANGE DATA MAP). THE OUTPUT ROW OF DISCRETE DERIVATIVE DATA CONTAINS OBJECT-RELATED DATA ONLY, AND MOST BACKGROUND NOISE WILL BE ELIMINATED.

I

STEP B4:AT EACH PROCESSING CYCLE, PERFORM A 2-D IMAGE-BASED CONTOUR TRACING OPERATION ON THE DISCRETE DERIVATIVE DATA CURRENTLY BUFFERED IN THE DIFF DATA BUFFER IN ORDER TO PRODUCE AN ARRAY OF m,n CONTOUR POINTS IN M-N SPACE (AND CORRESPONDING TO x,y CONTOUR POINTS IN X-Y CARTESIAN SPACE) TYPICALLY, THE ARRAY OF CONTOUR POINTS m,n WILL CORRESPOND TO THE SIDES OF THE POLYGONAL OBJECT EMBODIED IN THE ROWS OF OBJECT DATA CURRENTLY BUFFERED WITHIN THE OBJECT DATA BUFFER, AND THE OUTPUT DATA SET PRODUCED FROM THIS STEP OF THE METHOD CONTAINS EXTRANEOUS CORNER POINTS WHICH NEED TO BE REMOVED FROM THE PRODUCED ARRAY OF CONTOUR POINTS.

J

STEP B5: AT EACH PROCESSING CYCLE, STORE THE m,n INDICES (ASSOCIATED WITH THE CORNER POINTS OF THE TRACED CONTOURS) IN THE x-BOUNDARY AND y-BOUNDARY BUFFERS, RESPECTIVELY. NOTABLY, THE x-BOUNDARY AND y-BOUNDARY BUFFER IS M-256, AND THE LENGTH OF THE y-BOUNDARY BUFFER IS ALSO M=256

K

STEP B6: AT EACH PROCESSING CYCLE, DETECT THE m INDICES ASSOCIATED WITH "CORNER POINTS" IN THE TRACED CONTOURS BY CONVOLVING THE CURRENT DISCRETE DATA SET STORED IN THE x-BOUNDARY BUFFER (OF LENGTH M=256) WITH THE 11-TAP FIRFILTER (i.e. LOW-PASS 1st DIFFERENTIATOR) AND STORING THE RESULTANT DISCRETE m INDICE DATA SET IN THE x-TEMP ARRAY.

B

FIG. 20C

B

L

STEP B7: AT EACH PROCESSING CYCLE, DETECT THE n INDICES ASSOCIATED WITH THE "CORNER POINTS" IN THE TRACED CONTOURS BY CONVOLVING THE DISCRETE DATA SET STORED IN THE y-BOUNDRY BUFFER (OF LENGTH N) WITH THE 11-TAP FIR FILTER (i.e. LOW-PASS 1st DIFFERENTIATOR) AND THEN STORING THE RESULTANT DISCRETE n INDICE DATA SET IN THE y-TEMP-ARRAY.

M

STEP B8: AT EACH PROCESSING CYCLE, FIND THE "BREAK POINTS" AMONG THE DETECTED CORNER POINTS STORED IN THE x-TEMP - ARRAY AND y-TEMP-ARRAYS, AND BUFFER THE m AND n INDICES ASSOCIATED WITH THESE BREAK POINTS IN THE IN THE BREAKS BUFFER.

N

STEP B9: AT EACH PROCESSING CYCLE, PERFORMING LINEAR CURVE FITTING BETWEEN EVERY TWO CONSECUTIVE BREAK POINTS STORED IN THE BREAKS BUFFER, TO PRODUCE A SINGLE LINE REPRESENTATION THEREOF. EACH LINE CONSTITUTES A SIDE OF A POLYGON REPRESENTATION OF THE OBJECT REPRESENTED IN THE RANGE DATA MAP BUFFERED IN THE ODB OR f DATA BUFFER. FOR EVERY TWO CONSECTUTIVE SIDES OF THE POLYGON REPRESENTATION, THE INTERSECTION POINT IS DETERMINED, AND DEEMED A CORNER VERTEX OF THE POLYGON.

O

STEP B10: AT PROCESSING CYCLE, ONCE ALL CORNER COORDINATES (VERTICES) ARE OBTAINED, THE CORNER VERTICES ARE FURTHER REDUCDED USING A SHARP/DULL ANGLE ELIMINATION ALGORITHM AND CLOSE CORNER ELIMINATION OPERATORS. TYPICALLY, THE FINAL RESULT IS A SET OF m AND n INDICES CORRESPONDING TO THE x AND y COORDINATES ASSOCIATED WITH THE FOUR CORNERS COORDINATES OF A CUBIC BOX, WHICH SET IS THEREAFTER STORED IN A CORNER COORDINATE (OR INDICE) ARRAY.

C

FIG. 20D

C

P

STEP B11: COMPUTE THE AVERAGE RANGE VALUE OF THE CONTOUR POINTS CURRENTLY BUFFERED IN THE ODB SO AS TO PROVIDE AN AVERAGE HEIGHT VALUE FOR THE BOX , AND THEN, FOR EACH CORNER POINT IN THE CORNER COORDINATE ARRAY, USE THE COMPUTED AVERAGE RANGE VALUE TO COMPUTE THE z COORDINATE CORRESPONDING THERETO, AND REFERENCED WITH RESPECT TO THE GLOBAL COORDINATE FRAME OF REFERENCE.

Q

STEP B12: COMPUTE THE x AND y COORDINATES ASSOCIATED WITH EACH CORNER POINT CURRENTLY BUFFERED IN THE CORNER COORDINATE ARRAY AND SPECIFIED BY INDICES m AND n. COORDINATES x AND y ARE REFERENCED WITH RESPECT TO THE GLOBAL COORDINATE FRAME.

R

STEP B13: COMPUTE THE SURFACE AREA OF THE OBJECT REPRESENTED BY THE CONTOURS CURRENTLY REPRESENTED IN THE CONTOUR BUFFER, USING THE m,n COORDINATES ASSOCIATED WITH THE CORNER VERTICES m AND n CURRENTLY BUFFERED IN THE CORNER COORDINATE ARRAY.

S

STEP B14: FOR THE SCANNED OBJECT, OUTPUT THE COMPUTED SURFACE AREA, OBJECT HEIGHT, AND CORNER x,y COORDINATES (VERTICES) REFERENCED WITH RESPECT TO THE GLOBAL COORDINATE REFERENCE FRAME.

FIG. 20E

RAW RANGE DATA

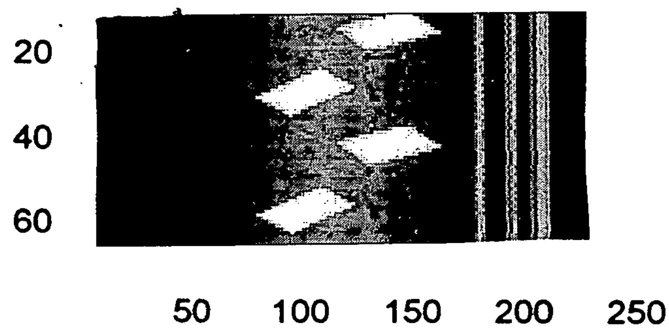


FIG. 21A

SMOOTHED RANGE DATA

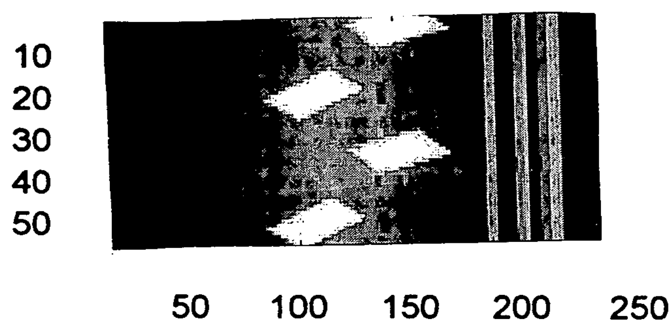


FIG. 21B

VERTICAL EDGE

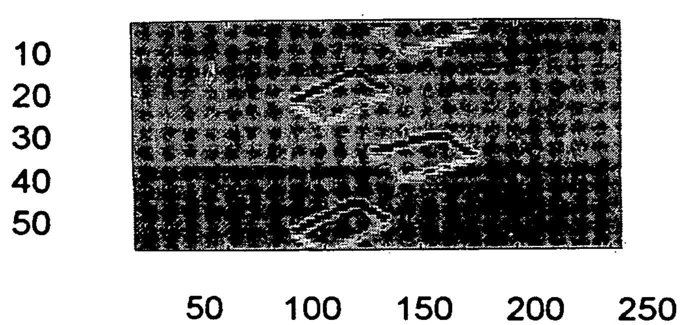


FIG. 21C

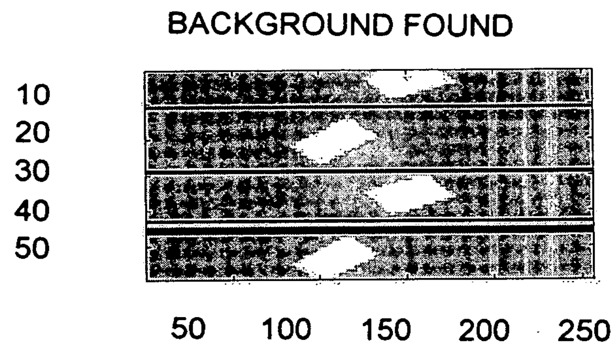


FIG. 21D

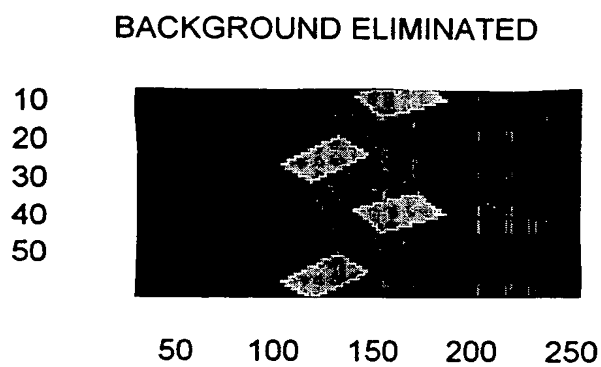
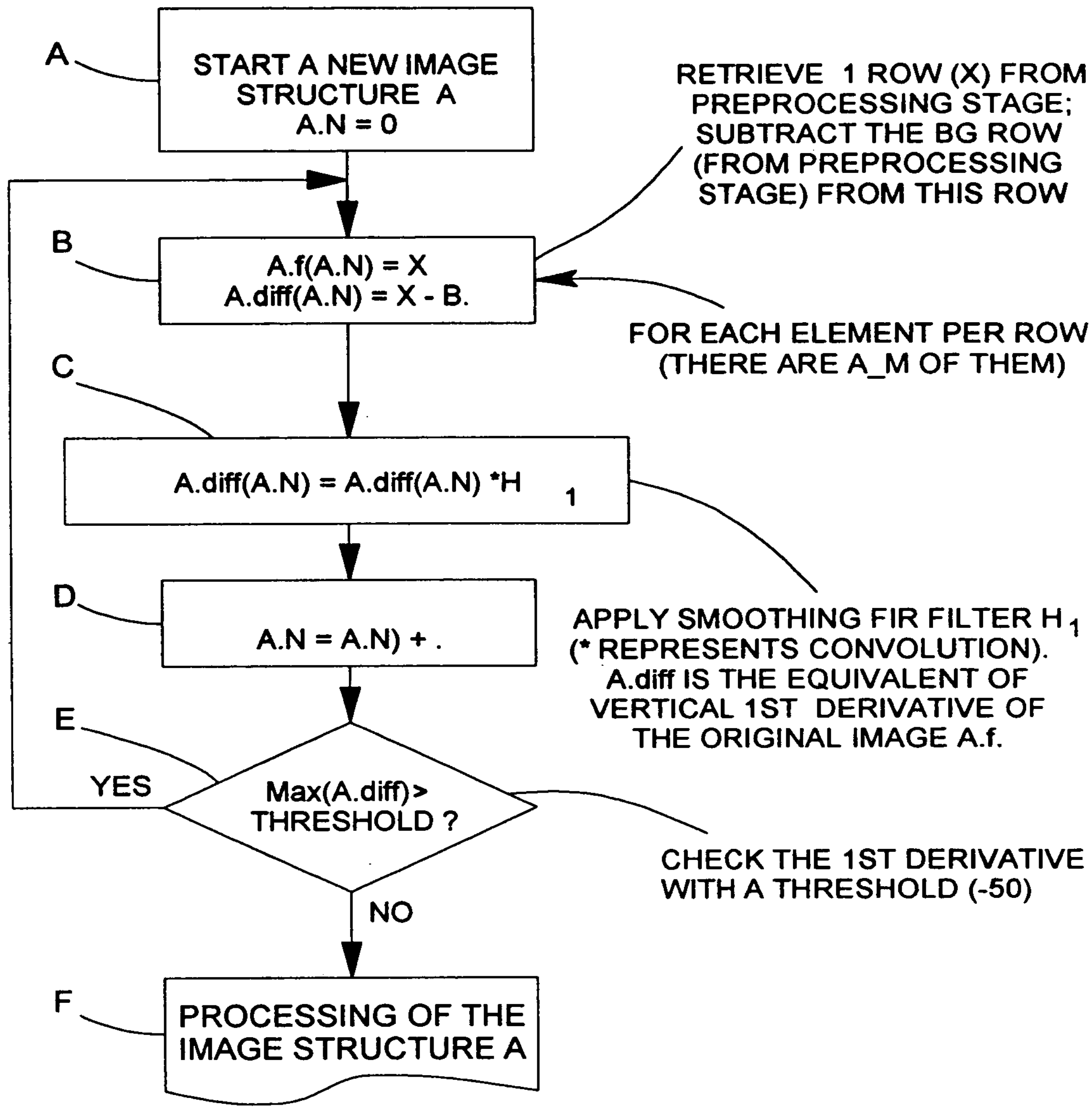


FIG. 21E



$H_1 = (0.15 \;\; 0.25 \;\; 0.2 \;\; 0.25 \;\; 0.15)$

THIS FUNCTIONAL BLOCK RETRIEVES DATA ALREADY PRE-PROCESSED, COMPUTES VERTICAL FIRST DERIVATIVE, AND STORES THE RESULTS IN AN IMAGE STRUCTURE FOR FURTHER PROCESSING, SUCH AS COMPUTER TRACING, ETC.

FIG. 22

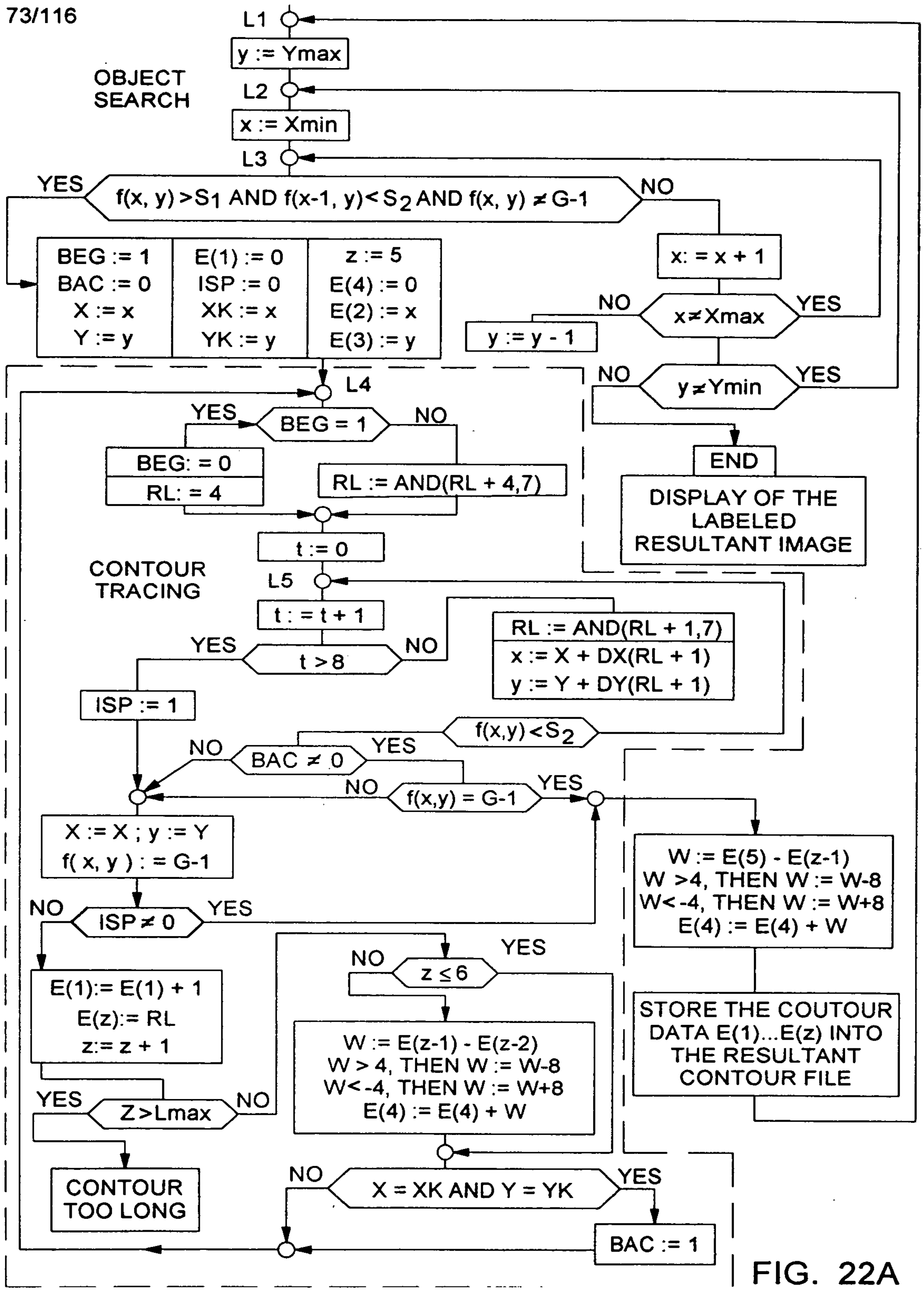

OBJECT SEARCH
L1
y := Ymax
L2
x := Xmin
L3
YES
f(x, y) > S1 AND f(x-1, y) < S2 AND f(x, y) ≠ G-1
NO
BEG := 1
BAC := 0
X := x
Y := y
E(1) := 0
ISP := 0
XK := x
YK := y
z := 5
E(4) := 0
E(2) := x
E(3) := y
x: = x + 1
NO
x≠Xmax
YES
y := y - 1
NO
y≠Ymin
YES
END
DISPLAY OF THE LABELED RESULTANT IMAGE
L4
YES
BEG = 1
NO
BEG: = 0
RL: = 4
RL := AND(RL + 4,7)
t := 0
CONTOUR TRACING
L5
t : = t + 1
RL := AND(RL + 1,7)
x := X + DX(RL + 1)
y := Y + DY(RL + 1)
YES
t > 8
NO
ISP := 1
f(x,y) < S2
NO
BAC ≠ 0
YES
NO
f(x,y) = G-1
YES
X := X ; y := Y
f(x, y) : = G-1
W := E(5) - E(z-1)
W > 4, THEN W := W-8
W < -4, THEN W := W+8
E(4) := E(4) + W
NO
ISP ≠ 0
YES
NO
z ≤ 6
YES
E(1):= E(1) + 1
E(z):= RL
z:= z + 1
W := E(z-1) - E(z-2)
W > 4, THEN W := W-8
W < -4, THEN W := W+8
E(4) := E(4) + W
STORE THE COUTOUR DATA E(1)...E(z) INTO THE RESULTANT CONTOUR FILE
YES
Z > Lmax
NO
CONTOUR TOO LONG
NO
X = XK AND Y = YK
YES
BAC := 1

FIG. 22A

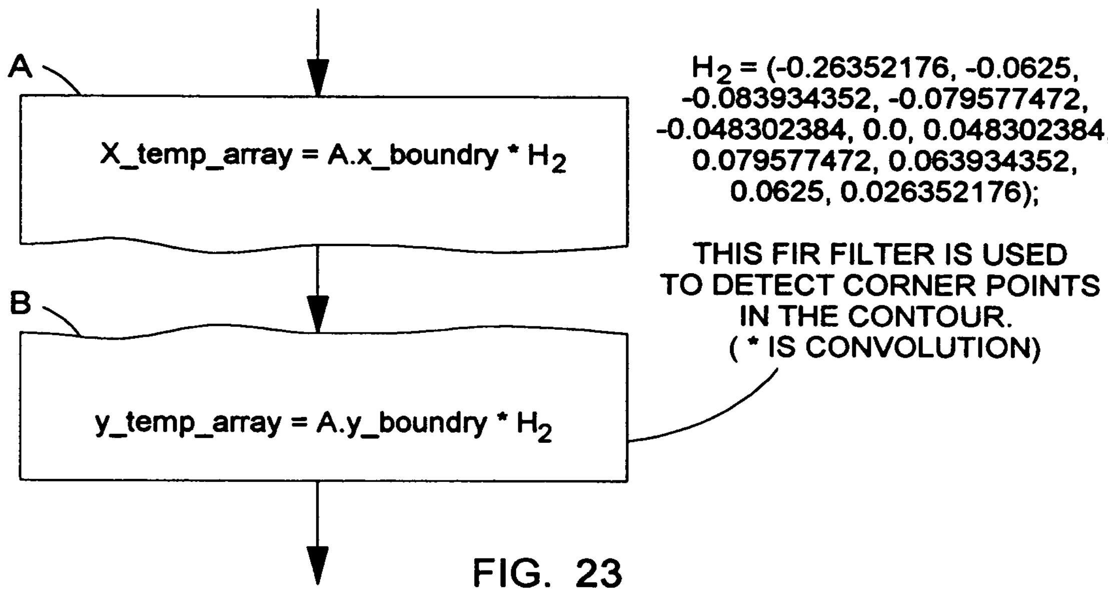

A
X_temp_array = A.x_boundry * H2
B
y_temp_array = A.y_boundry * H2
H2 = (-0.26352176, -0.0625, -0.083934352, -0.079577472, -0.048302384, 0.0, 0.048302384, 0.079577472, 0.063934352, 0.0625, 0.026352176);
THIS FIR FILTER IS USED TO DETECT CORNER POINTS IN THE CONTOUR. (* IS CONVOLUTION)

FIG. 23

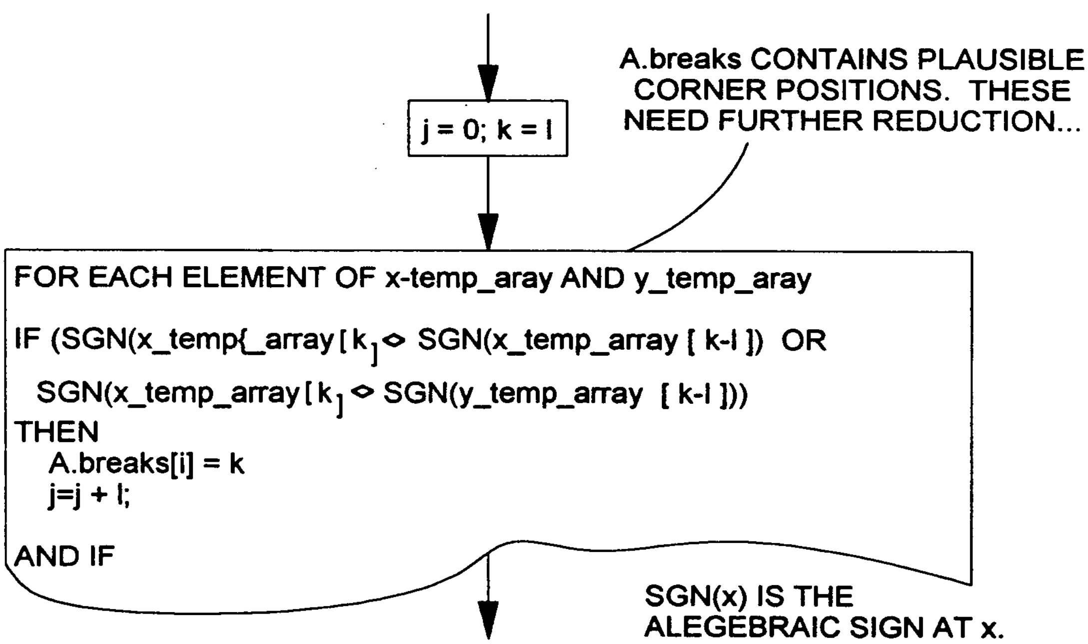
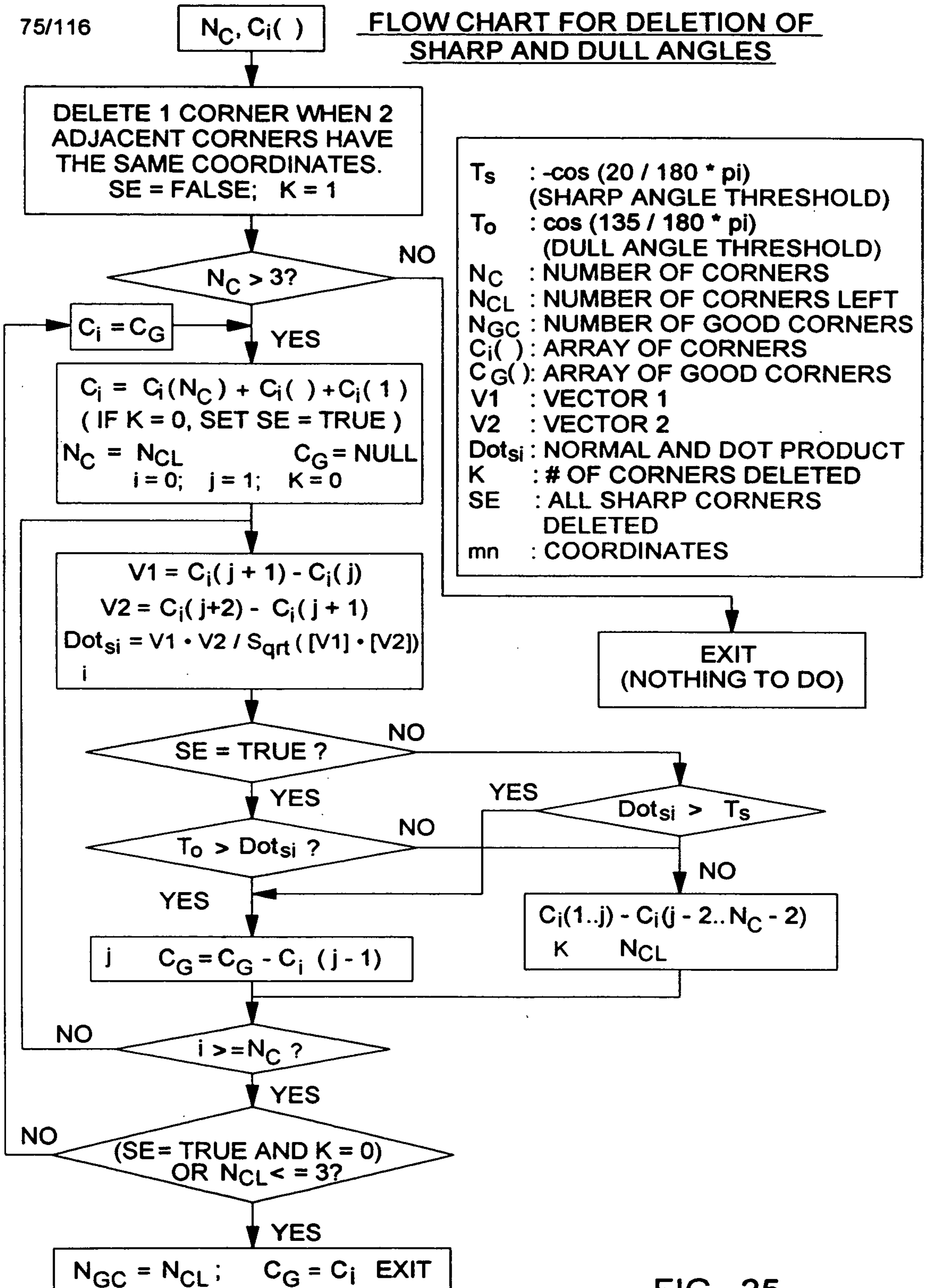

j = 0; k = l
A.breaks CONTAINS PLAUSIBLE CORNER POSITIONS. THESE NEED FURTHER REDUCTION...
FOR EACH ELEMENT OF x-temp_aray AND y_temp_aray
IF (SGN(x_temp{_array [k] <> SGN(x_temp_array [k-l]) OR
SGN(x_temp_array [k] <> SGN(y_temp_array [k-l]))
THEN
A.breaks[i] = k
j=j + l;
AND IF
SGN(x) IS THE ALEGEBRAIC SIGN AT x.

FIG. 24



FLOW CHART FOR DELETION OF SHARP AND DULL ANGLES
NC, Ci( )
DELETE 1 CORNER WHEN 2 ADJACENT CORNERS HAVE THE SAME COORDINATES. SE = FALSE; K = 1
NC > 3?
NO
YES
Ci = CG
Ci = Ci(NC) + Ci( ) + Ci(1)
(IF K = 0, SET SE = TRUE)
NC = NCL CG = NULL
i = 0; j = 1; K = 0
V1 = Ci(j + 1) - Ci(j)
V2 = Ci(j+2) - Ci(j + 1)
Dotsi = V1 • V2 / Sqrt ([V1] • [V2])
i
SE = TRUE ?
NO
YES
To > Dotsi ?
NO
YES
Dotsi > Ts
YES
NO
j CG = CG - Ci (j - 1)
Ci(1..j) - Ci(j - 2..NC - 2)
K NCL
i >= NC ?
NO
YES
(SE = TRUE AND K = 0) OR NCL <= 3?
NO
YES
NGC = NCL; CG = Ci EXIT
EXIT (NOTHING TO DO)
Ts : -cos (20 / 180 * pi) (SHARP ANGLE THRESHOLD)
To : cos (135 / 180 * pi) (DULL ANGLE THRESHOLD)
NC : NUMBER OF CORNERS
NCL : NUMBER OF CORNERS LEFT
NGC : NUMBER OF GOOD CORNERS
Ci( ) : ARRAY OF CORNERS
CG( ): ARRAY OF GOOD CORNERS
V1 : VECTOR 1
V2 : VECTOR 2
Dotsi : NORMAL AND DOT PRODUCT
K : # OF CORNERS DELETED
SE : ALL SHARP CORNERS DELETED
mn : COORDINATES

FIG. 25

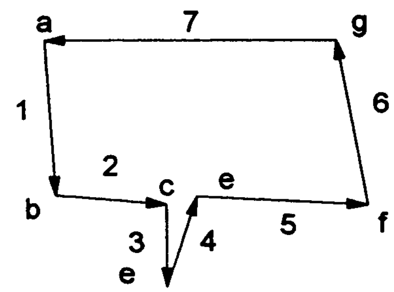


FIG. 26A

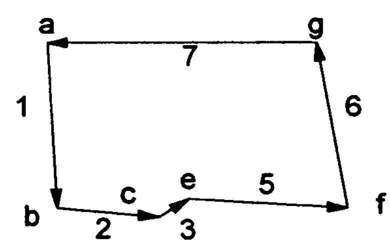


FIG. 26B

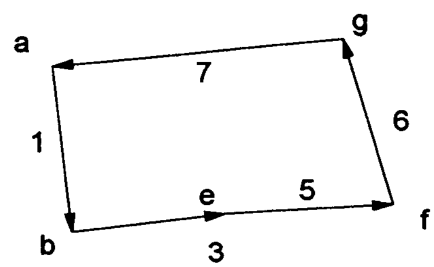


FIG. 26C

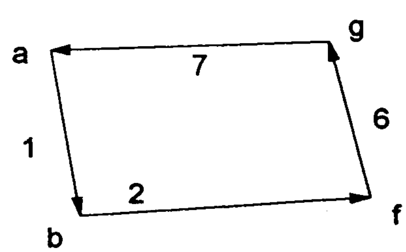


FIG. 26D

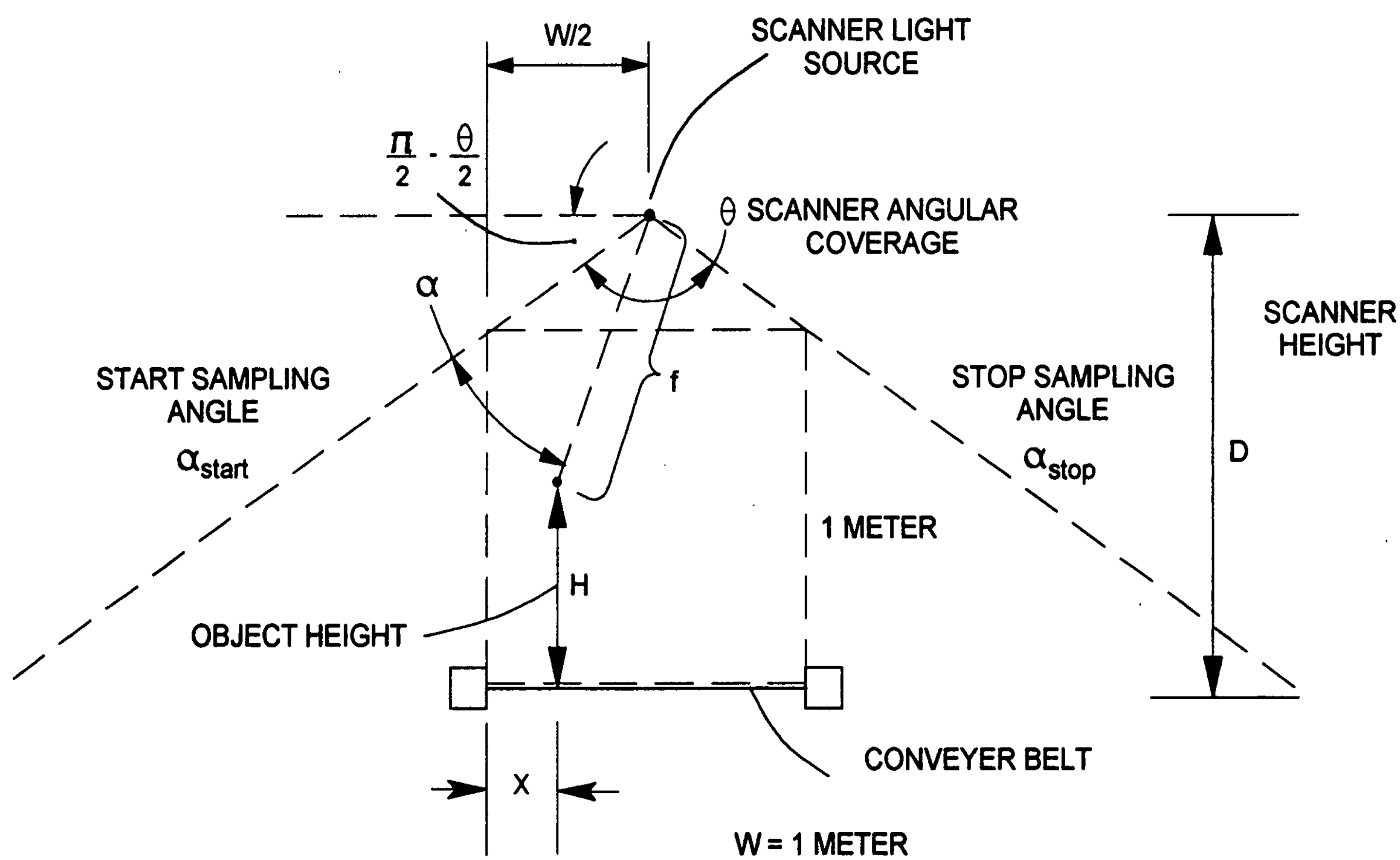

W/2
SCANNER LIGHT SOURCE
$\frac{\pi}{2} - \frac{\theta}{2}$
θ SCANNER ANGULAR COVERAGE
α
SCANNER HEIGHT
START SAMPLING ANGLE α_{start}
f
STOP SAMPLING ANGLE α_{stop}
D
1 METER
H
OBJECT HEIGHT
CONVEYER BELT
X
W = 1 METER

FIG. 27

FLOW CHART FOR PACKAGE AREA COMPUTATION

OAB	TRIANGLE WITH VERTEXES O, A AND B
N_V	NUMBER OF VERTEXES
VAB	VECTOR AB
ANG1	ANGLE OF FIRST VECTOR
ANG2	ANGLE OF SECOND VECTOR
L1	LENGTH OF FIRST VECTOR
L2	LENGTH OF SECOND VECTOR

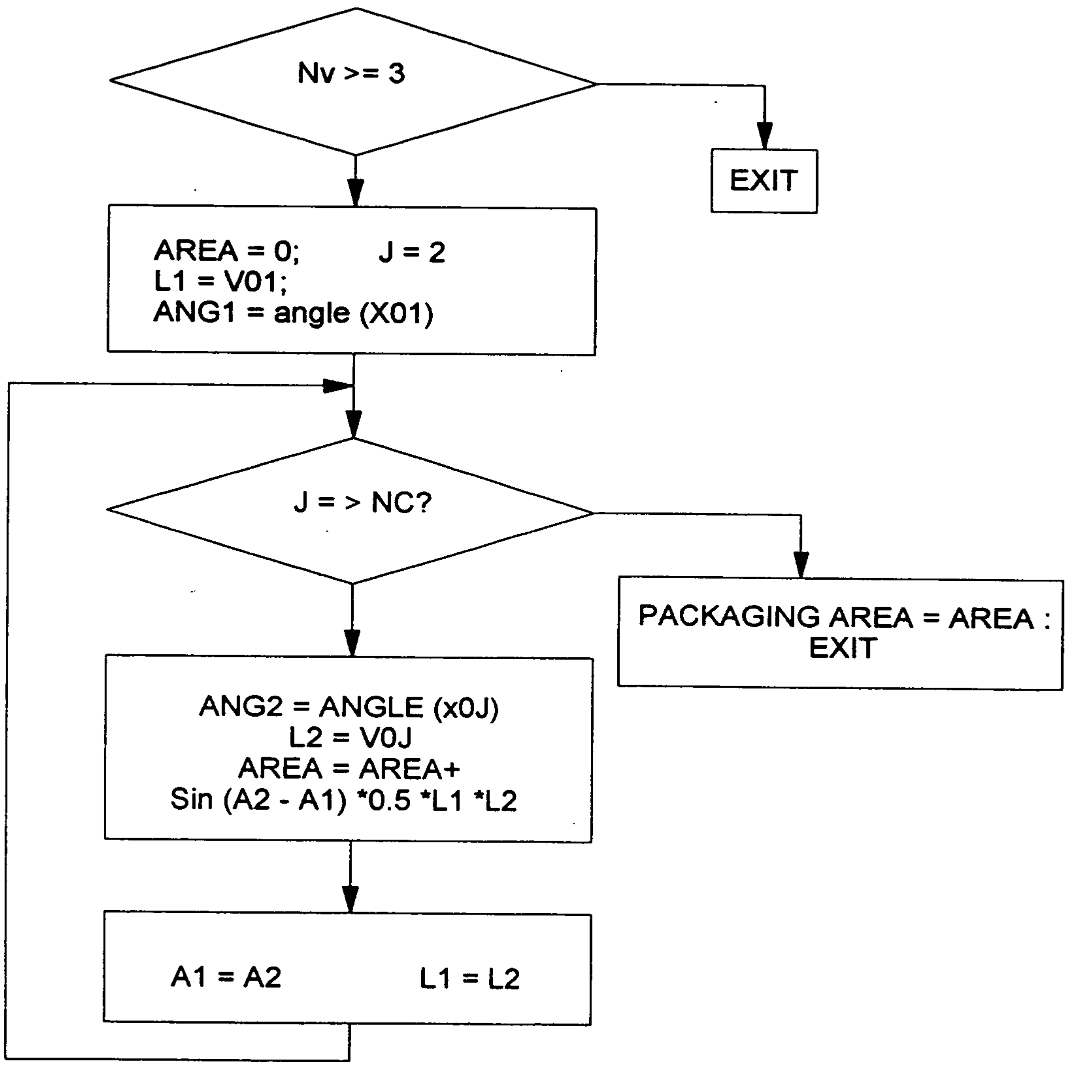


FIG. 28

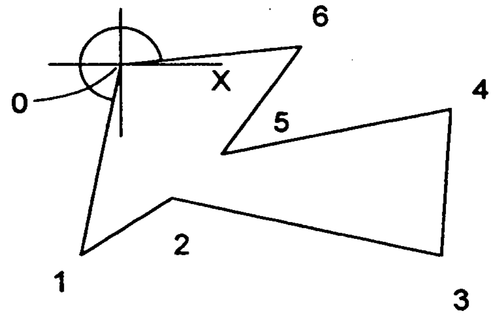


FIG. 29A

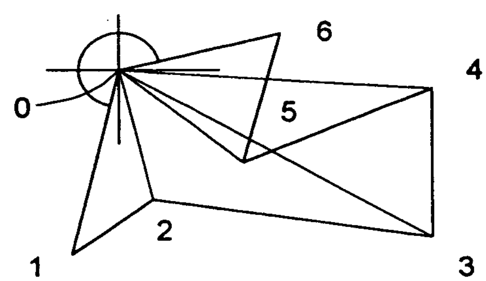


FIG. 29B

PACKAGE VELOCITY MEASUREMENT
SUBSYSTEM (400)

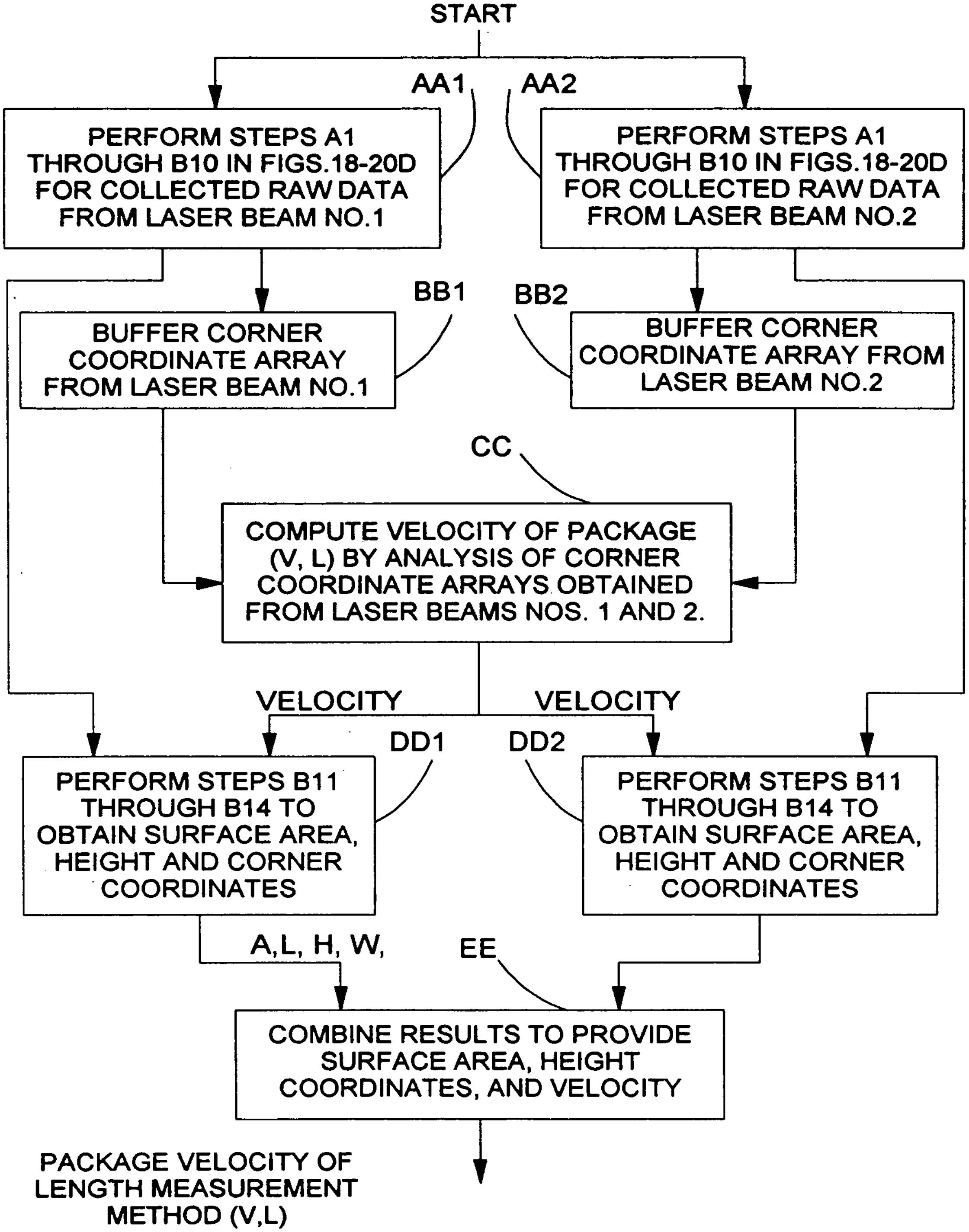


FIG. 30

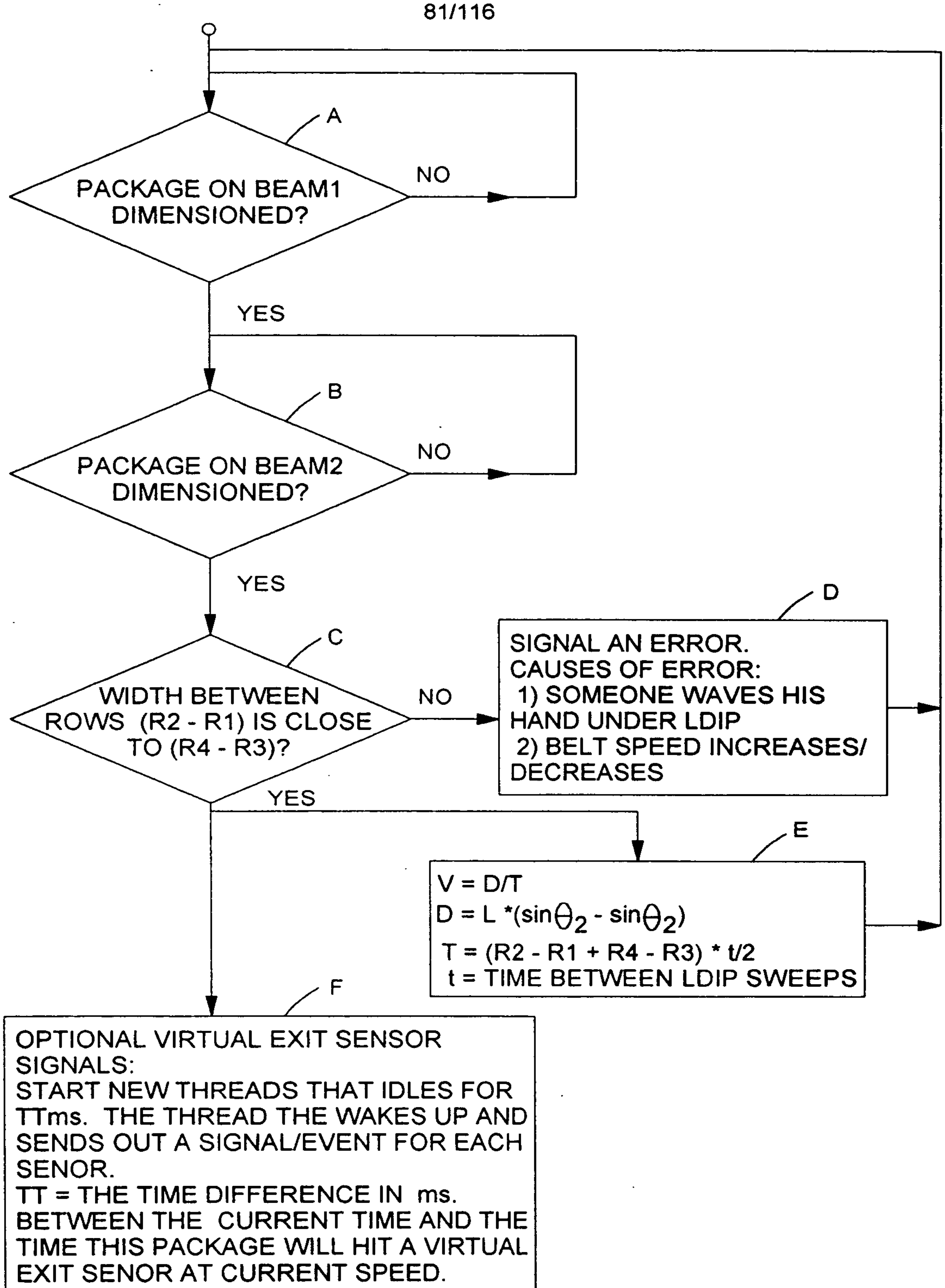

A
PACKAGE ON BEAM1 DIMENSIONED?
NO
YES
B
PACKAGE ON BEAM2 DIMENSIONED?
NO
YES
C
WIDTH BETWEEN ROWS (R2 - R1) IS CLOSE TO (R4 - R3)?
NO
D
SIGNAL AN ERROR.
CAUSES OF ERROR:
1) SOMEONE WAVES HIS HAND UNDER LDIP
2) BELT SPEED INCREASES/ DECREASES
YES
E
V = D/T
D = L *(sinθ2 - sinθ2)
T = (R2 - R1 + R4 - R3) * t/2
t = TIME BETWEEN LDIP SWEEPS
F
OPTIONAL VIRTUAL EXIT SENSOR SIGNALS:
START NEW THREADS THAT IDLES FOR TTms. THE THREAD THE WAKES UP AND SENDS OUT A SIGNAL/EVENT FOR EACH SENOR.
TT = THE TIME DIFFERENCE IN ms. BETWEEN THE CURRENT TIME AND THE TIME THIS PACKAGE WILL HIT A VIRTUAL EXIT SENOR AT CURRENT SPEED.

FIG. 31

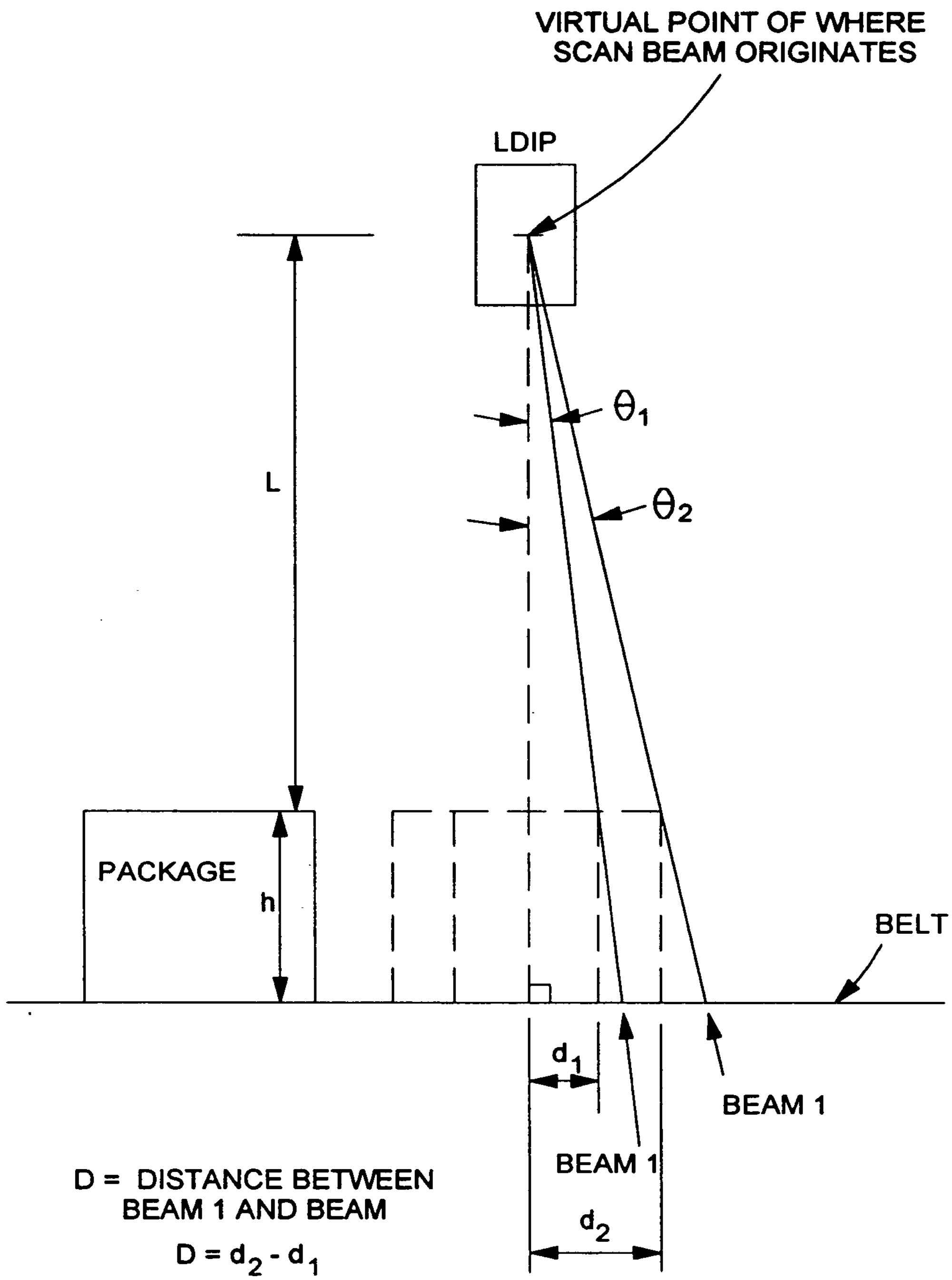

VIRTUAL POINT OF WHERE SCAN BEAM ORIGINATES
LDIP
L
θ_1
θ_2
PACKAGE
h
BELT
d_1
BEAM 1
BEAM 1
d_2
D = DISTANCE BETWEEN BEAM 1 AND BEAM
$D = d_2 - d_1$

FIG. 32

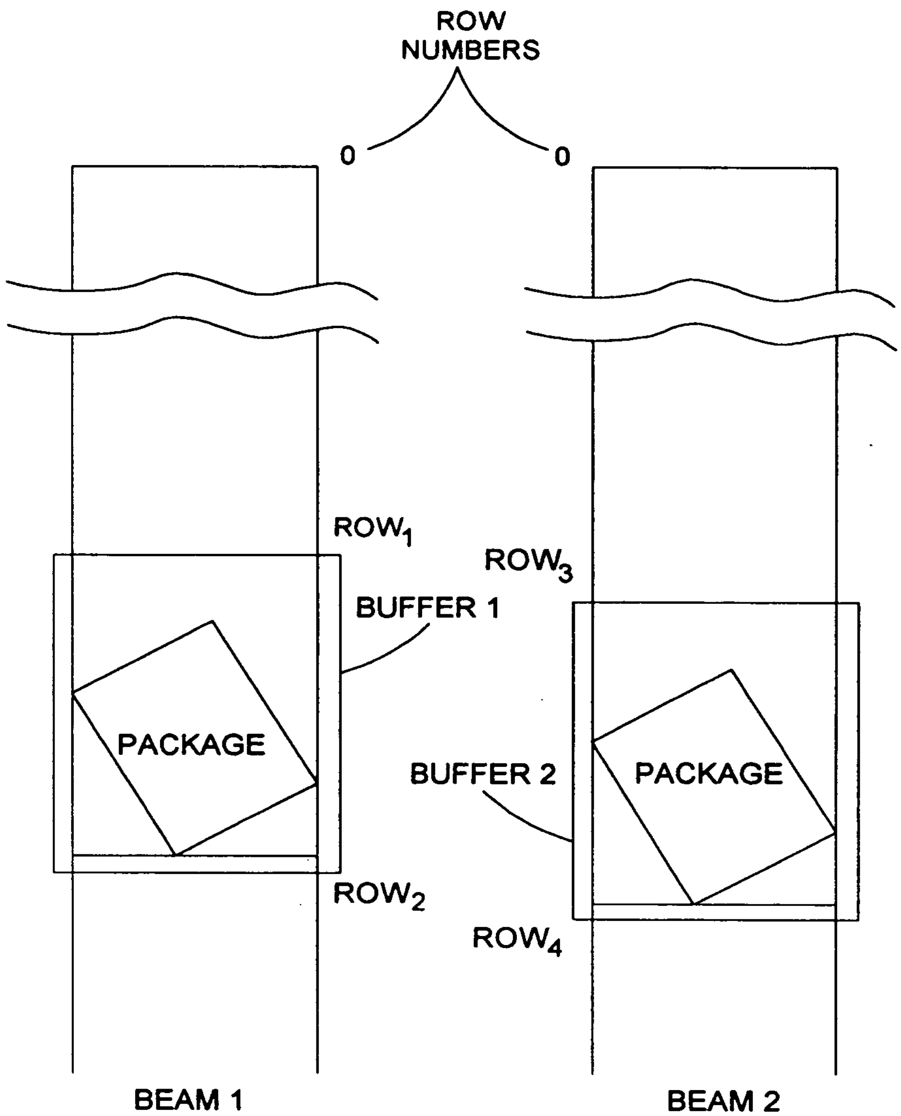


FIG. 33A

FIG. 33B

PACKAGE IN THE TUNNEL(PITT) INDICATION SUBSYSTEM (500)

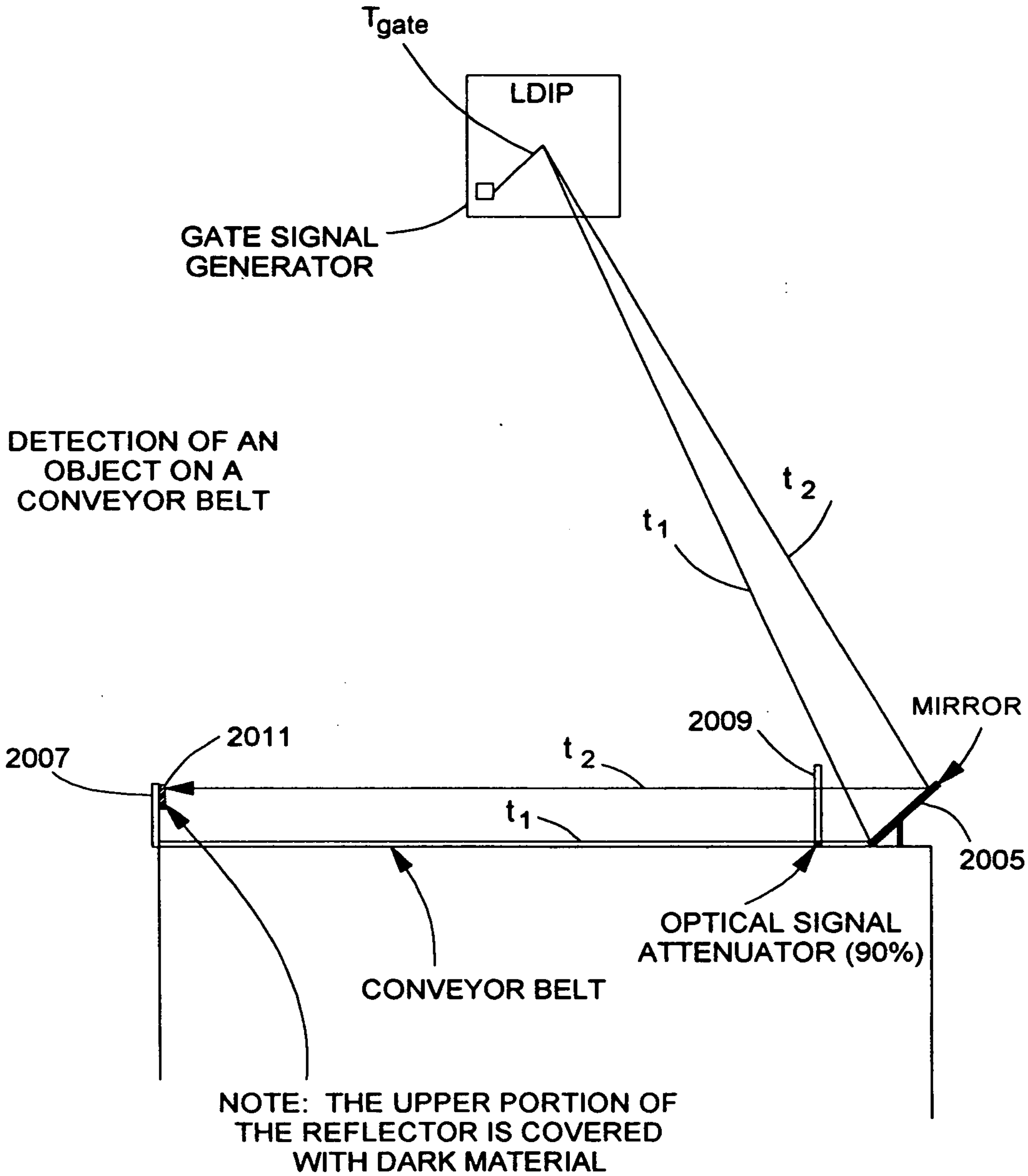


FIG. 33A

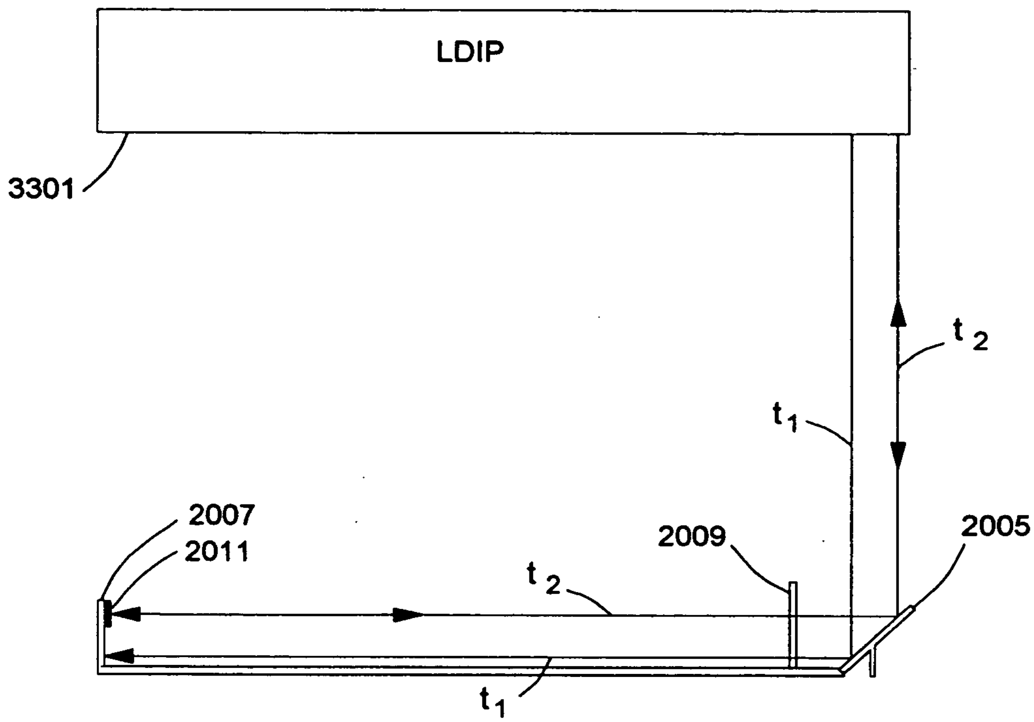


FIG. 33B

A

GENERATE "START-OF-OBJECT SENSING" CYCLE PULSE SIGNAL AS AM-LASER IS SCANNED ALONG EDGE OF CONVEYOR BELT. THE LADAR-BASED IMAGE AND PROFILING SUBSYSTEM OF THE PRESENT INVENTION.

B

USE "START-OF-OBJECT SENSING" CYCLE PULSE SIGNAL TO GENERATE A PREDEFINED TIME WINDOW OVER WHICH DETECTION OF OBJECT SENSING SIGNAL WILL OCCUR.

C

TRANSMIT AN OBJECT SENSING SIGNAL ACROSS THE CONVEYOR BELT, AND DETECT CHANGES IN THE INTENSITY OF THIS SIGNAL OVER THE PREDEFIED TIME WINDOW.

D

GENERATE AN OBJECT DETECTION SIGNAL IN RESPONSE TO THE DETECTION OF CHANGES IN INTENSITY IN THE OBJECT SENSING SIGNAL, INDICATIVE OF THE PRESENCE OF AN OBJECT (i.e. PACKAGE) MOVING ACROSS THE CONVEYOR BELT.

FIG. 34

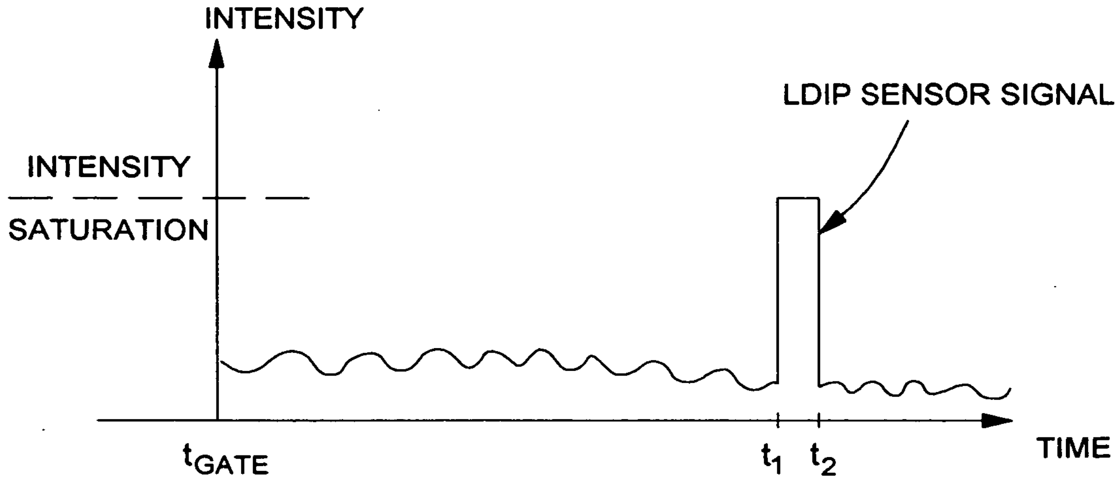


FIG. 35A

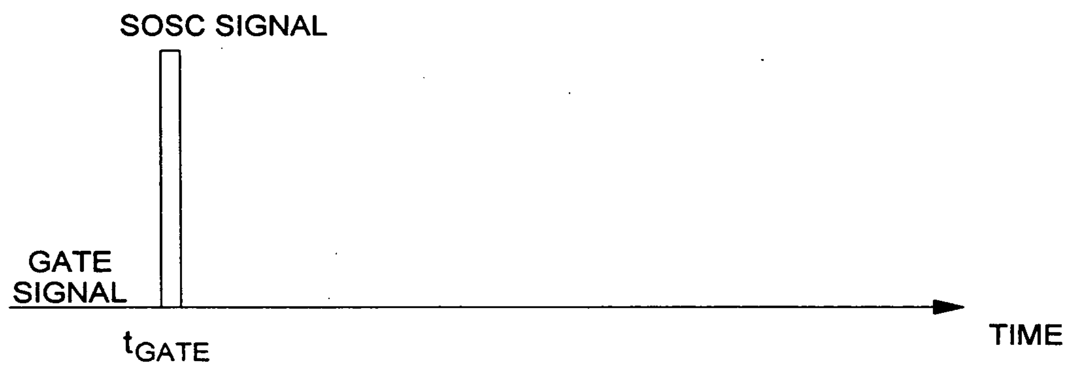


FIG. 35B

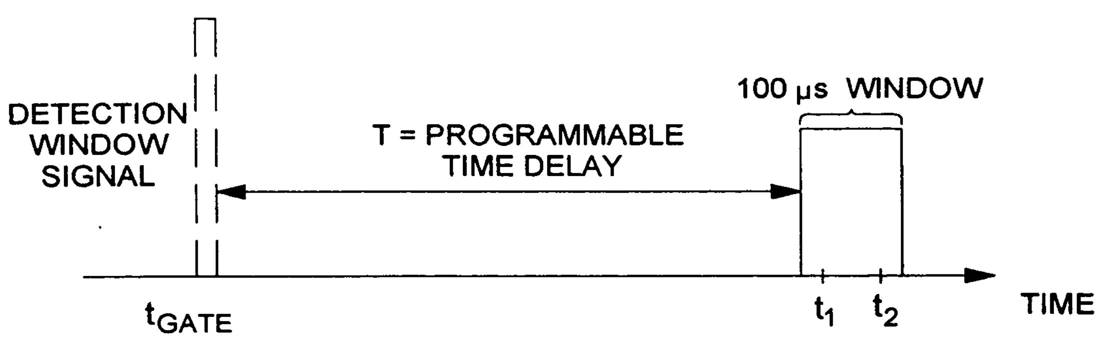


FIG. 35C

TABLE 1

											t1			t2								
-13	-12	-7	-2	2	12	8	97	160	479	580	813	1129	276	161	286	404	411	403	149	106	81	68
FIRST DERIVATIVE																						
										-8.02	-185	-135	-137	-401	74.28	-683	390	697.6	-217	-4.7	-71	114.3

FIG. 36A

TABLE 2

FIR FILTER TABS										
-0.2	0.25	-0.33	0.5	-1	0	1	-0.5	0.33	-0.25	0.2

FIG. 36B

TABLE 3

											t1			t2								
-11	-6	-2	2	6	42	18	105	172	463	594	684	197	105	79	102	338	375	387	177	96	72	61
FIRST DERIVATIVE																						
										-22.3	-123	-8.8	-257	-191	-205	184.3	429.3	-153	182	-214	-45.9	1.783

FIG. 36C

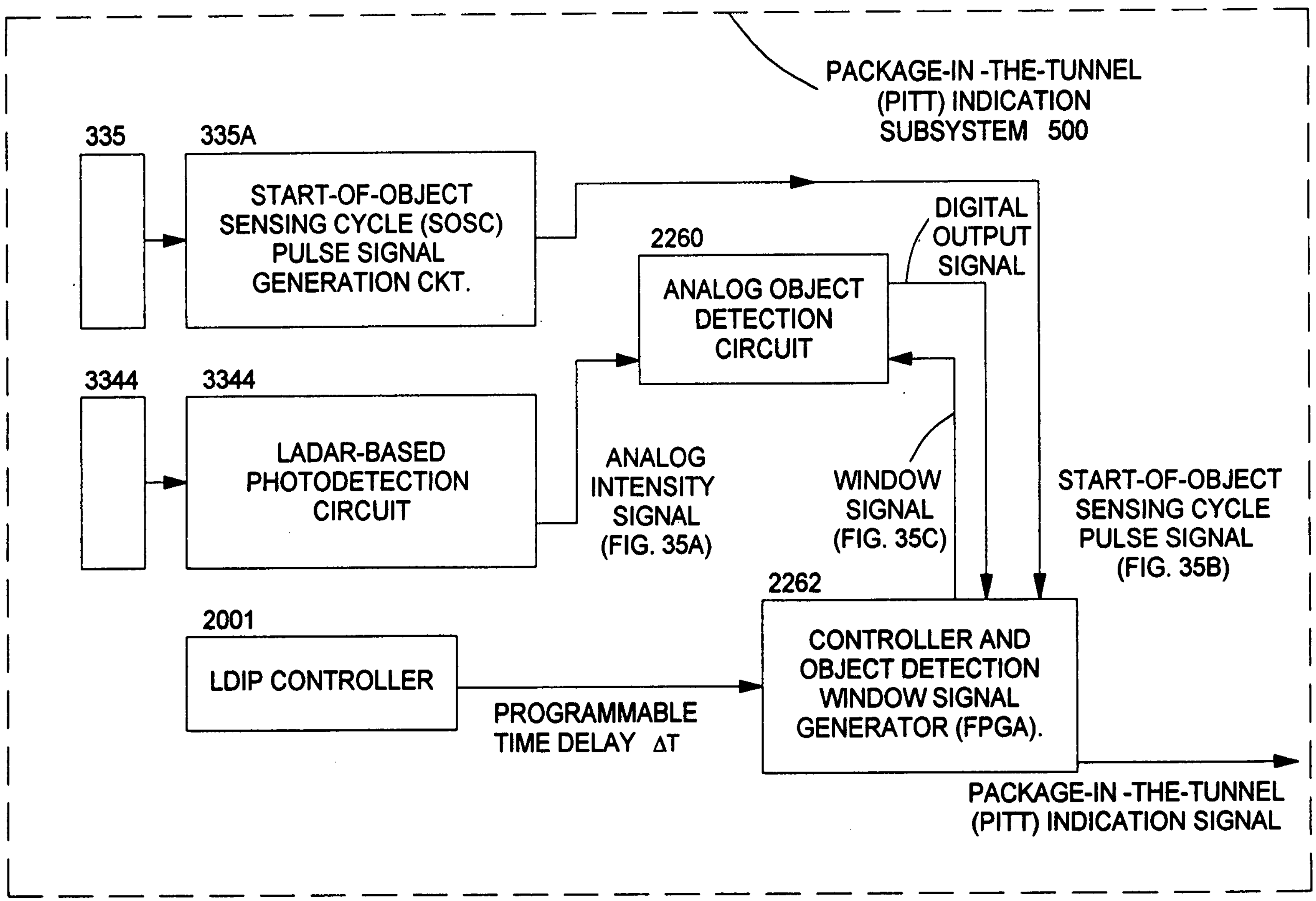

PACKAGE-IN -THE-TUNNEL (PITT) INDICATION SUBSYSTEM 500
335
335A
START-OF-OBJECT SENSING CYCLE (SOSC) PULSE SIGNAL GENERATION CKT.
2260
ANALOG OBJECT DETECTION CIRCUIT
DIGITAL OUTPUT SIGNAL
3344
3344
LADAR-BASED PHOTODETECTION CIRCUIT
ANALOG INTENSITY SIGNAL (FIG. 35A)
WINDOW SIGNAL (FIG. 35C)
START-OF-OBJECT SENSING CYCLE PULSE SIGNAL (FIG. 35B)
2262
2001
LDIP CONTROLLER
PROGRAMMABLE TIME DELAY ΔT
CONTROLLER AND OBJECT DETECTION WINDOW SIGNAL GENERATOR (FPGA).
PACKAGE-IN -THE-TUNNEL (PITT) INDICATION SIGNAL

FIG. 37

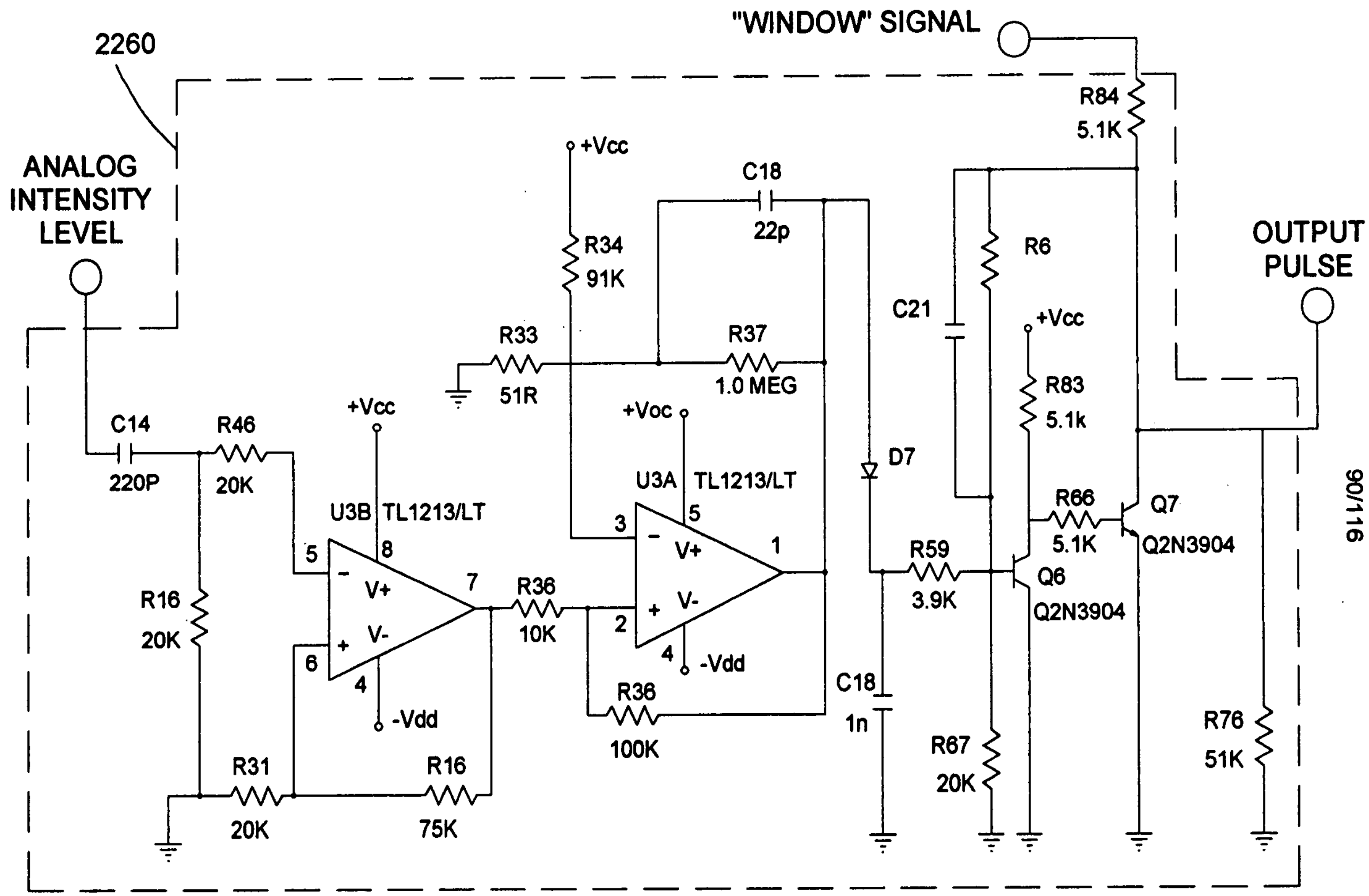

2260
ANALOG INTENSITY LEVEL
"WINDOW" SIGNAL
OUTPUT PULSE
C14
220P
R46
20K
R16
20K
R31
20K
R16
75K
+Vcc
U3B
TL1213/LT
-Vdd
R36
10K
R33
51R
R34
91K
+Vcc
C18
22p
R37
1.0 MEG
+Voc
U3A
TL1213/LT
-Vdd
R36
100K
D7
C18
1n
R59
3.9K
C21
R6
+Vcc
R83
5.1k
R66
5.1K
Q6
Q2N3904
Q7
Q2N3904
R67
20K
R84
5.1K
R76
51K

FIG. 38

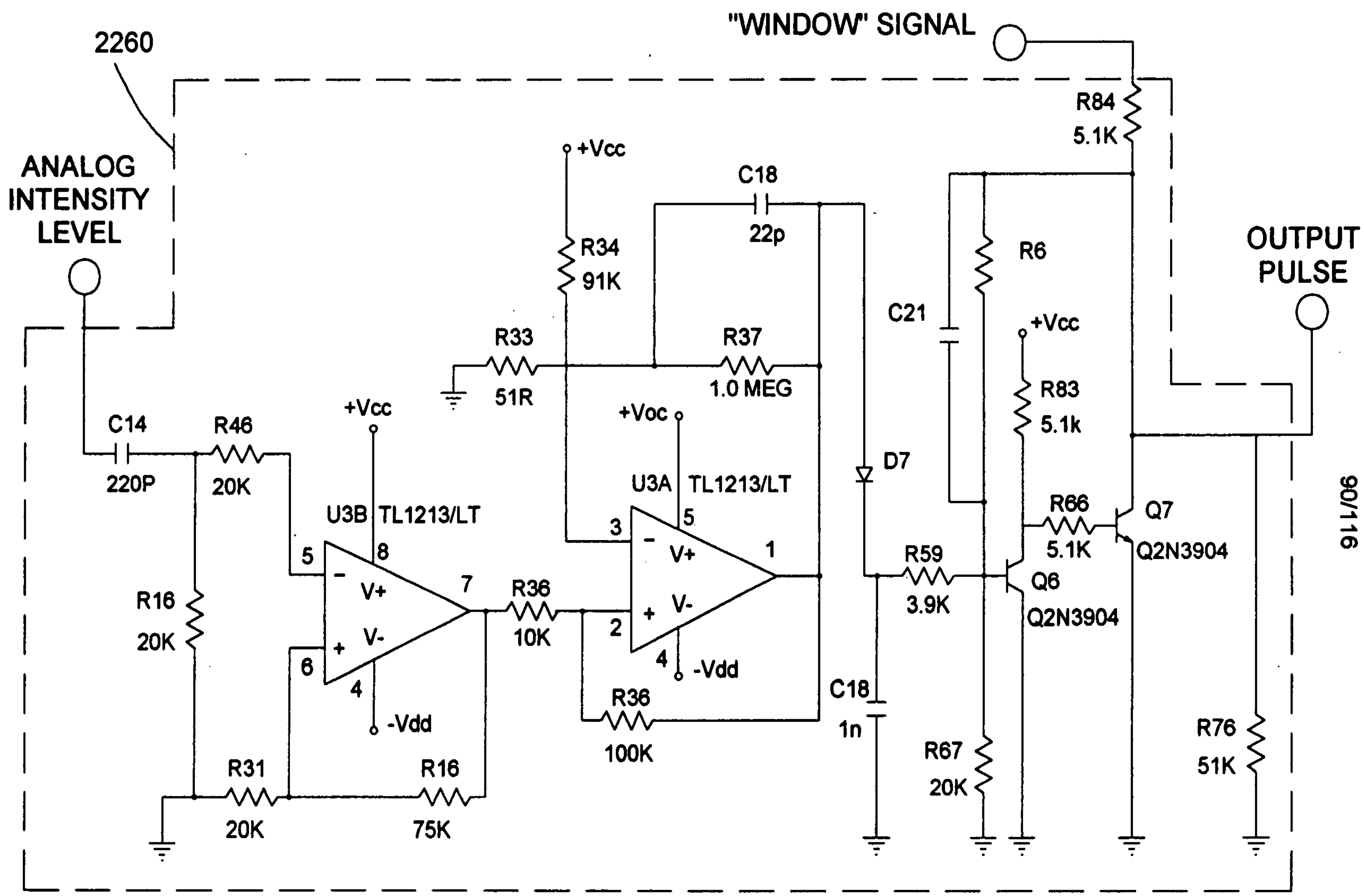
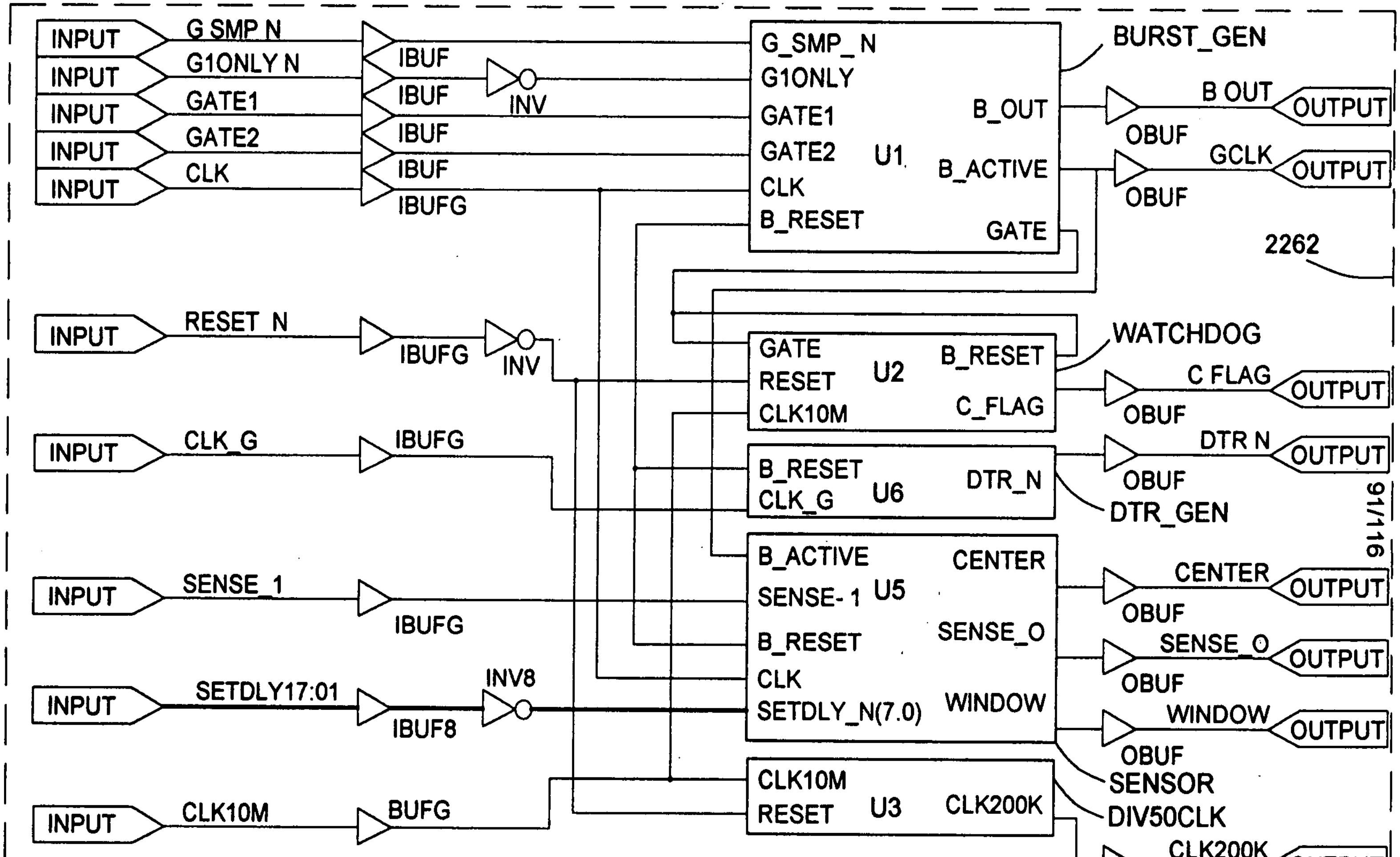

2260
ANALOG
INTENSITY
LEVEL
"WINDOW" SIGNAL
OUTPUT
PULSE
C14
220P
R46
20K
R16
20K
R31
20K
R16
75K
+Vcc
U3B
TL1213/LT
-Vdd
R36
10K
R34
91K
R33
51R
C18
22p
R37
1.0 MEG
+Voc
U3A
TL1213/LT
-Vdd
R36
100K
D7
C18
1n
R59
3.9K
C21
R6
+Vcc
R83
5.1k
R66
5.1K
Q6
Q2N3904
Q7
Q2N3904
R67
20K
R84
5.1K
R76
51K

FIG. 38



FOR SINGLE GATE: USE GATE 1 & GROUND GATE 2 INPUT; GATE 1 ONLY (N) INPUT = LOW

FOR DUAL GATES: GATE 1 STARTS SEQENCE AFTER RESET; GATE 1 ONLY (N) INPUT = HIGH

G_SMP_N = LOW FOR GATE FILTER SAMPLING MODE. SENSE_O HIGH = UNBROKEN SENSOR BEAM(DEFAULT)

FIG. 39

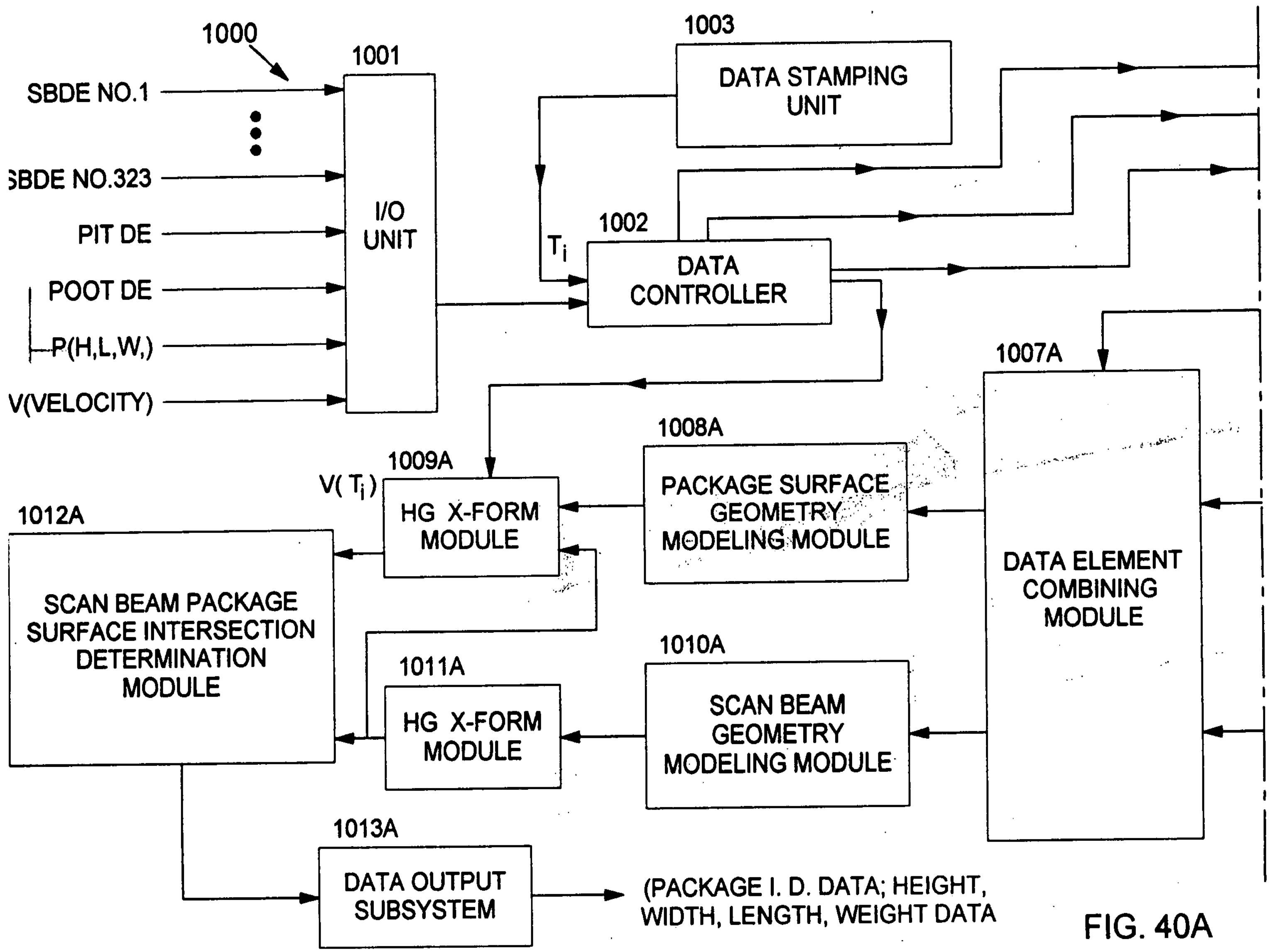

1000
SBDE NO.1
SBDE NO.323
PIT DE
POOT DE
P(H,L,W,)
V(VELOCITY)
1001
I/O UNIT
1003
DATA STAMPING UNIT
1002
T_i
DATA CONTROLLER
1007A
DATA ELEMENT COMBINING MODULE
1008A
PACKAGE SURFACE GEOMETRY MODELING MODULE
1009A
$V(T_i)$
HG X-FORM MODULE
1010A
SCAN BEAM GEOMETRY MODELING MODULE
1011A
HG X-FORM MODULE
1012A
SCAN BEAM PACKAGE SURFACE INTERSECTION DETERMINATION MODULE
1013A
DATA OUTPUT SUBSYSTEM
(PACKAGE I. D. DATA; HEIGHT, WIDTH, LENGTH, WEIGHT DATA

FIG. 40A

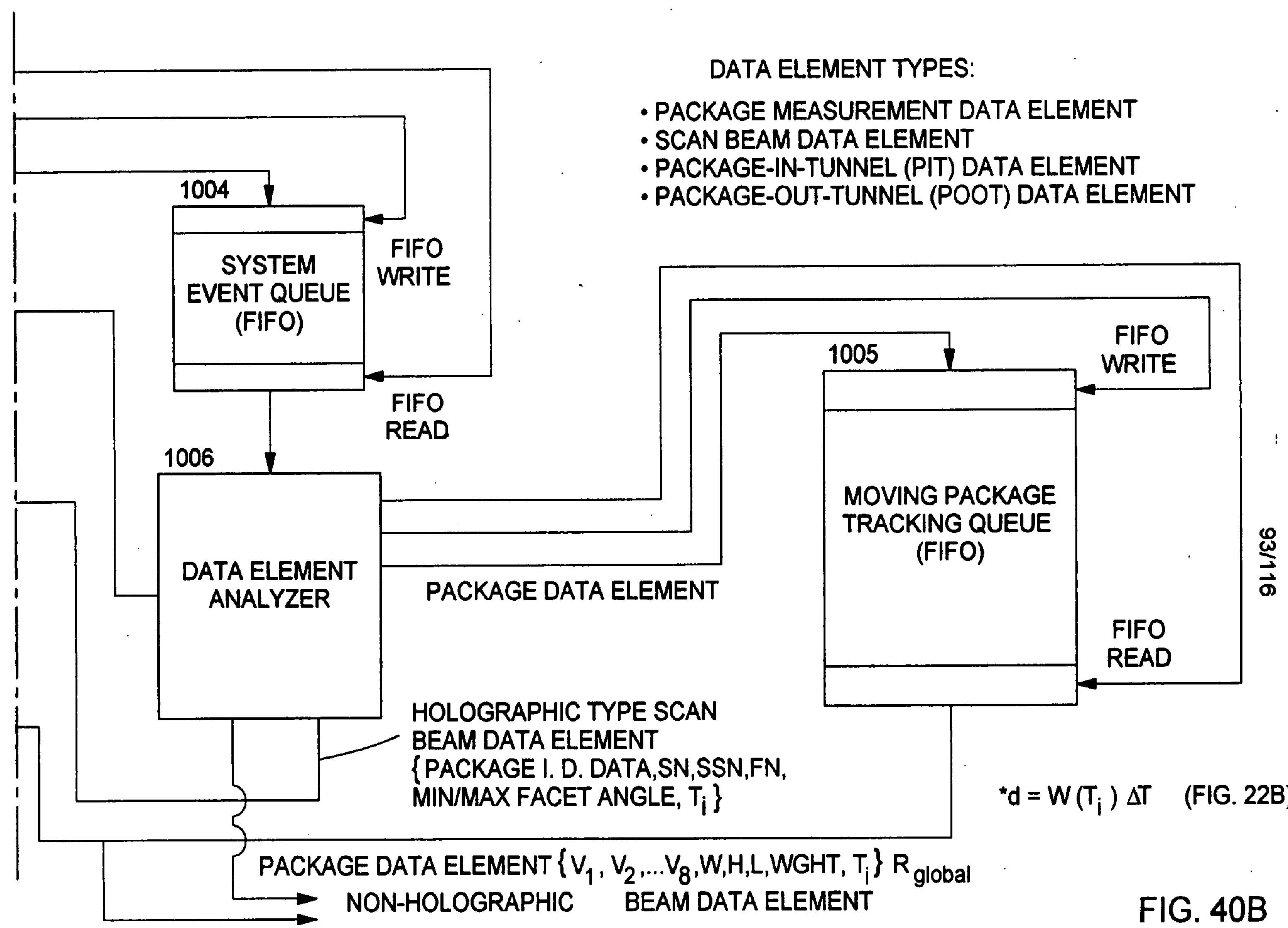

DATA ELEMENT TYPES:
• PACKAGE MEASUREMENT DATA ELEMENT
• SCAN BEAM DATA ELEMENT
• PACKAGE-IN-TUNNEL (PIT) DATA ELEMENT
• PACKAGE-OUT-TUNNEL (POOT) DATA ELEMENT
1004
SYSTEM EVENT QUEUE (FIFO)
FIFO WRITE
FIFO READ
1006
DATA ELEMENT ANALYZER
1005
MOVING PACKAGE TRACKING QUEUE (FIFO)
FIFO WRITE
FIFO READ
PACKAGE DATA ELEMENT
HOLOGRAPHIC TYPE SCAN BEAM DATA ELEMENT
{PACKAGE I. D. DATA,SN,SSN,FN, MIN/MAX FACET ANGLE, T_i}
PACKAGE DATA ELEMENT {V_1, V_2,...V_8,W,H,L,WGHT, T_i} R_{global}
NON-HOLOGRAPHIC
BEAM DATA ELEMENT
*d = W (T_i) ΔT (FIG. 22B)

FIG. 40B

DATA ELEMENT HANDLING RULES

1. WHEN A PACKAGE DATA ELEMENT (PDE) OF ANY TYPE IS REMOVED FROM THE SYSTEM EVENT QUEUE, THEN IT IS PLACED IN THE MOVING PACKAGE TRACKING QUEUE

2. WHEN A SCAN BEAM DATA ELEMENT (SBDE) IS REMOVED FROM THE SYSTEM EVENT QUEUE, THEN IT IS COMBINED WITH EACH PACKAGE DATA ELEMENT IN THE MOVING PACKAGE TRACKING QUEUE AND THEN EACH RESULTING DATA ELEMENT PAIR IS PROCESSED ALONG THE PACKAGE DATA ELEMENT CHANNEL AND SCAN DATA ELEMENT CHANNEL AS SHOWN IN FIGS. 40A & 40B

3. WHEN A PACKAGE-IN-TUNNEL (PIT) DATA ELEMENT IS REMOVED FROM THE SYSTEM EVENT QUEUE, THEN THE OLDEST PACKAGE DATA ELEMENT IN THE MOVING PACKAGE TRACKING QUEUE IS REMOVED THERE FROM

4. WHEN A PACKAGE OUT-OF TUNNEL (POOT) DATA ELEMENT IS REMOVED FROM THE SYSTEM EVENT QUEUE, THEN THE FOLLOWING OPERATIONS ARE CARRIED OUT

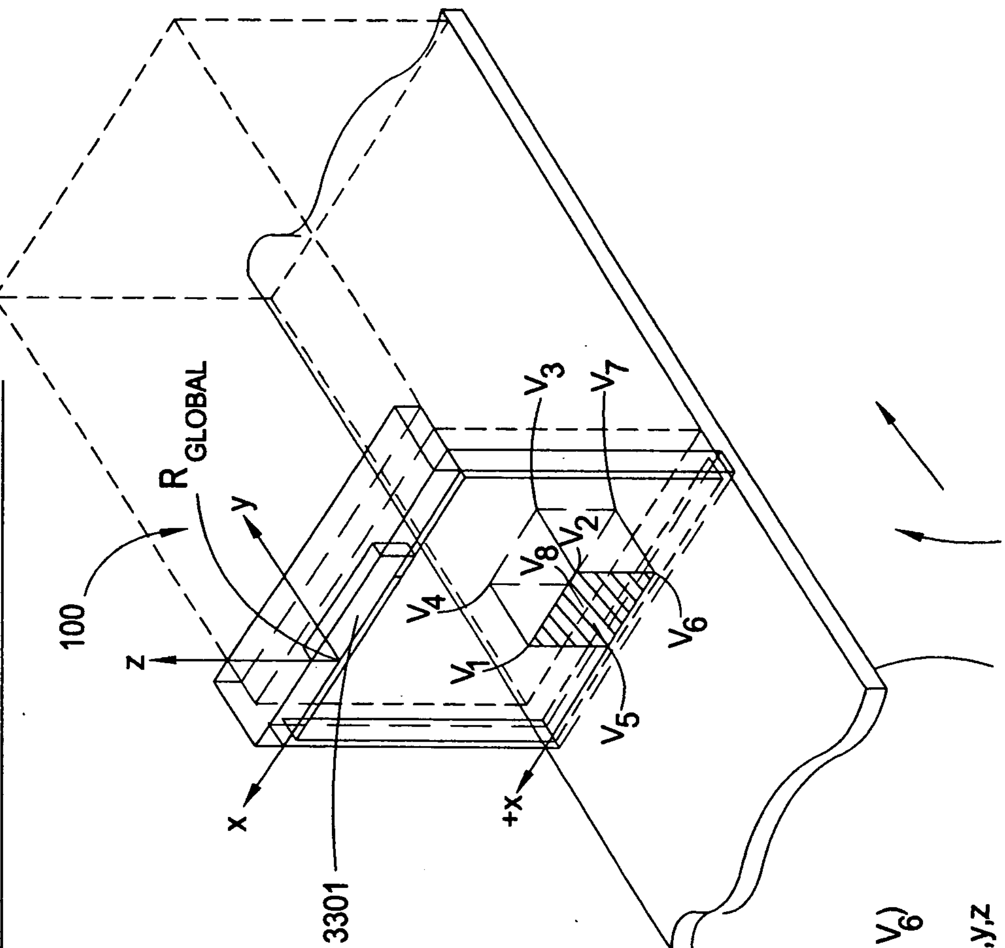
FIG. 41A

(a) IF THE TIME STAMP T_i ON THE REMOVED POOT DATA ELEMENT INDICATES THAT CORRESPONDING PACKAGE HAS MOVED OUT OF THE SCANNING TUNNEL, THEN REMOVE THE OLDEST PACKAGE DATA ELEMENT IN MOVING PACKAGE TRACKING QUEUE

(b) IF THE TIME STAMP T_i ON THE REMOVED POOT DATA ELEMENT INDICATES THAT THE CORRESPONDING PACKAGE IS STILL MOVING THROUGH THE SCANNING TUNNEL, THEN DO NOT REMOVE ANY PACKAGE DATA ELEMENT FROM THE MOVING PACKAGE TRACKING QUEUE.

FIG. 41B

PACKAGE SURFACE GEOMETRY MODELING



$S(V_1, V_2, V_5, V_6)$

$V_1 = x,y,z$

FIG. 42

VECTOR-BASED SURFACE MODELING OF PACKAGES MOVING IN SCANNING TUNNEL

MATHEMATICAL FORM OF EACH SURFACE ON THE PACKAGE: VECTOR-BASED MODEL CONSISTING OF (1) AT LEAST THREE VERTICE POINTS WITHIN THE PLANE OF THE PACKAGE SURFACE, AND (2) NORMAL VECTOR FOR THE PLANE.

PROCEDURE:

(1) USE POSITION VECTOR (REFERENCED TO X=0, Y=0,Z=0 IN R_{global}), FOR SPECIFYING THE POSITION OF EACH VERTEX IN THE PACKAGE SURFACE PLANE; AND

(2) USE NORMAL VECTOR FOR SPECIFYING THE SURFACE DIRECTION OF THE PACKAGE SURFACE (AT WHICH LIGHT REFLECTS)

(3) THEDE FOUR VECTORS S[ECIFU THE SURFACE OR THE PACKAGE IN COOEDINATE REFERENCE FROM R_{global}

FIG. 43

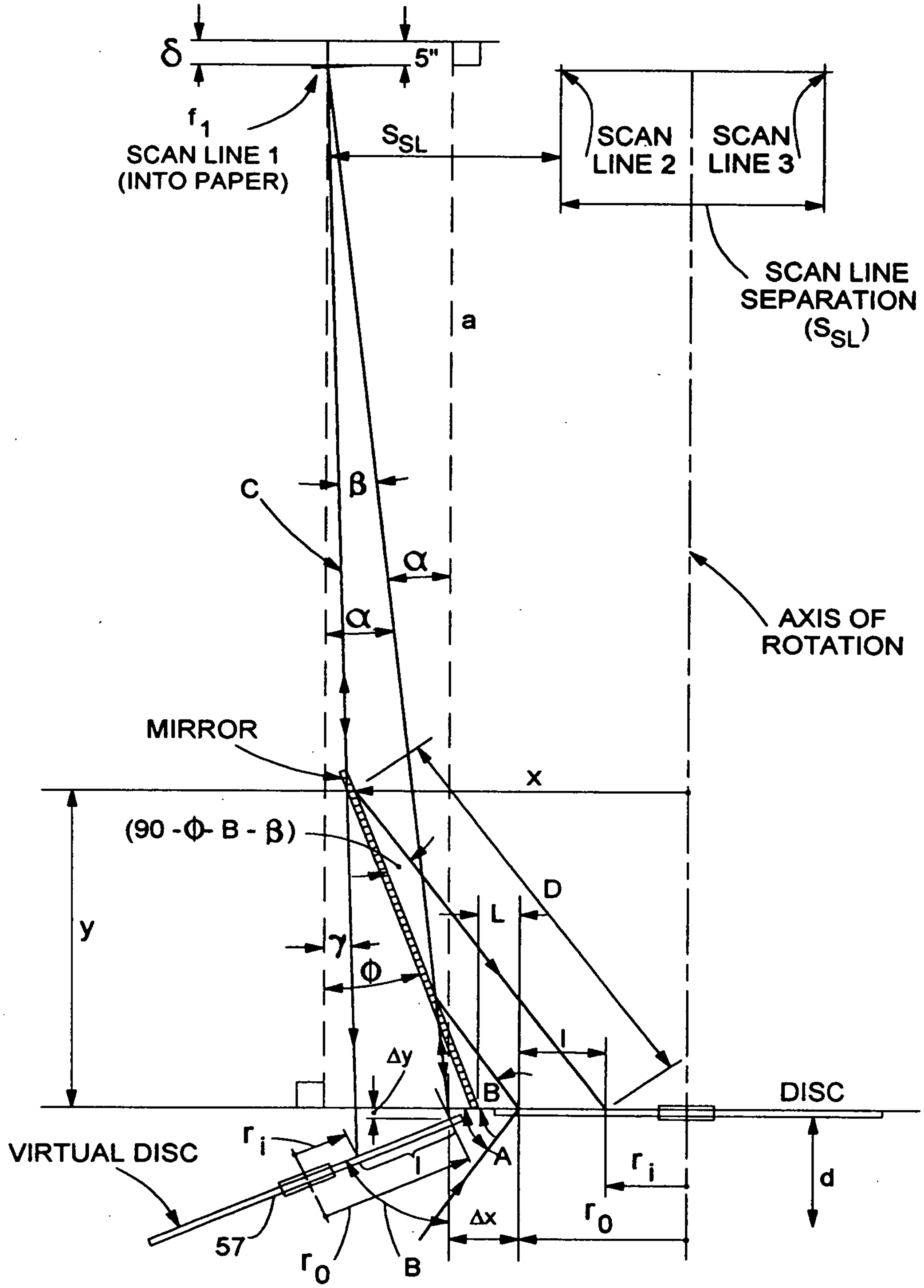

δ
5"
f_1
SCAN LINE 1
(INTO PAPER)
S_{SL}
SCAN LINE 2
SCAN LINE 3
SCAN LINE
SEPARATION
(S_{SL})
a
C
β
α
α
AXIS OF
ROTATION
MIRROR
x
(90 - Φ - B - β)
D
L
y
γ
Φ
l
Δy
B
DISC
r_i
VIRTUAL DISC
l
A
r_i
d
Δx
r_0
57
r_0
B

FIG. 44A1

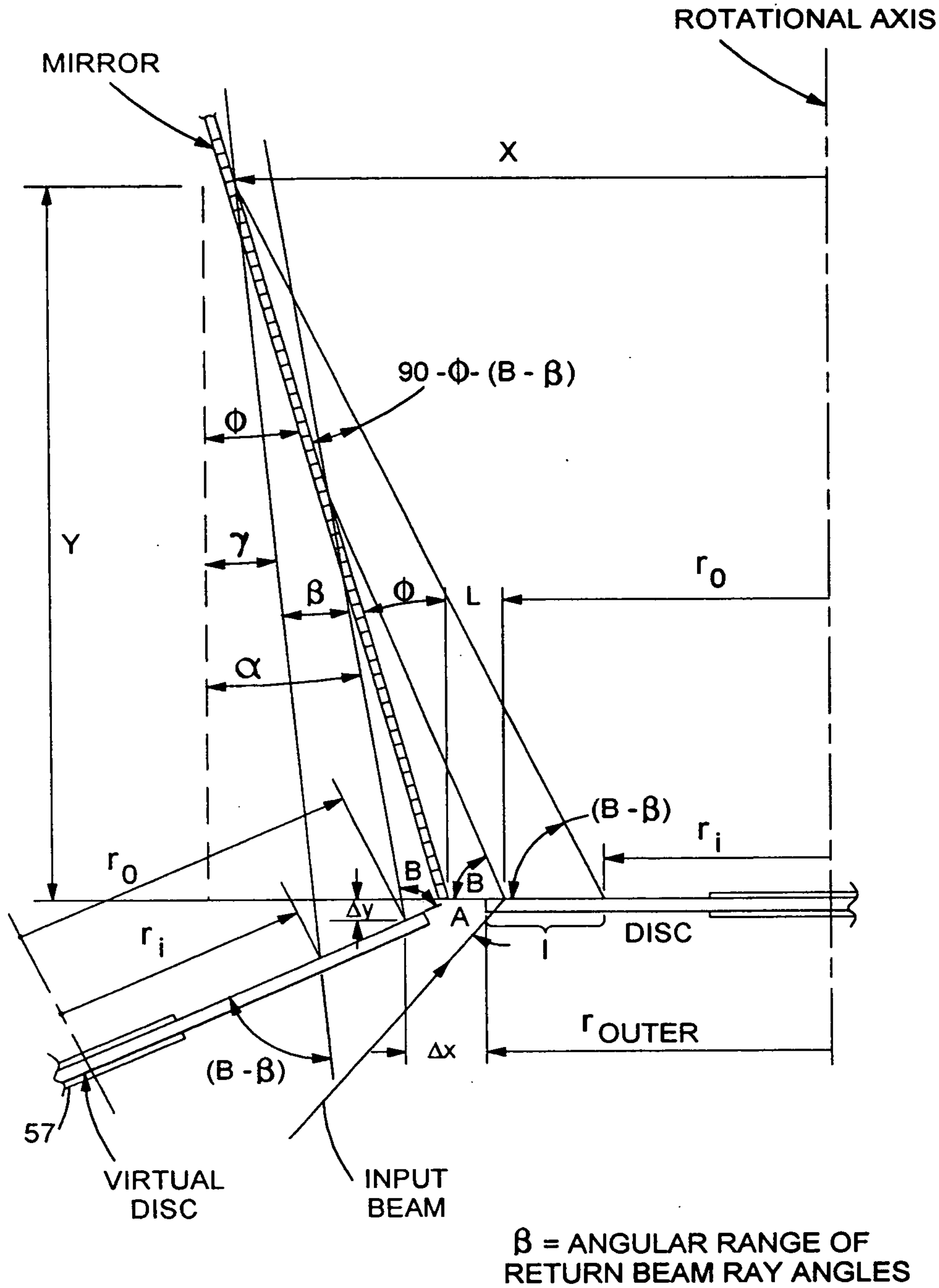

ROTATIONAL AXIS
MIRROR
X
Y
90 -Φ- (B - β)
Φ
γ
β
Φ
L
r_0
α
(B -β)
r_i
r_0
B
B
Δy
A
r_i
DISC
l
r_{OUTER}
(B -β)
Δx
57
VIRTUAL DISC
INPUT BEAM
β = ANGULAR RANGE OF RETURN BEAM RAY ANGLES

FIG. 44A2

(1) THE RADIUS TO BEAM-INCIDENT-POINT ON THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "r_0"

(2) SCANLINE SEPARATION BETWEEN ADJACENT SCANLINES AT THE FOCAL PLANE OF THE (i,J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION "S_{SL}"

(3) THE SCANLINE LENGTH (MEASURED INTO PAPER) FOR THE (i,J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION "L_{SL}"

(4) THE DISTANCE MEASURED FROM THE SCANNING DISC TO THE FOCAL PLANE OF THE (i,J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION a_i

(5) THE DISTANCE FROM RADIUS TO BEAM-INCIDENT-POINT r_O TO BEAM FOLDING MIRROR, ASSIGNED THE SYMBOLIC NOTATION "L"

(6) THE TILT ANGLE OF THE J-TH BEAM FOLDING MIRROR ASSOCIATED WITH GENERATION OF THE (i,J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION "ϕ_j"

(7) THE TILT ANGLE OF THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "2ϕ"

(8) THE LATERAL SHIFT OF THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "ΔX"

(9) THE VERTICAL SHIFT OF THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "ΔY"

(10) THE DISTANCE FROM THE ROTATION AXIS TO THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "$r_0 + \Delta X$"

(11) THE DISTANCE FROM THE BEAM INCIDENT POINT ON THE VIRTUAL SCANNING DISC TO THE FOCAL PLANE WITHIN WHICH THE (i,J)-TH SCANLINE RESIDES, ASSIGNED THE SYMBOLIC NOTATION "f_i"

(12) THE DIAMETER OF THE CROSS-SECTION OF THE LASER BEAM SCANNING STATION, ASSIGNED THE SYMBOLIC NOTATION "d_{BEAM}"

(13) THE ANGULAR GAP BETWEEN ADJACENT HOLOGRAPHIC SCANNING FACETS, ASSIGNED THE SYMBOLIC NOTATION "d_{GAP}"

(14) THE OUTER RADIUS OF THE AVAILABLE LIGHT COLLECTION REGION ON THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "r_{OUTER}"

FIG. 44B1

(15) THE INNER RADIUS OF THE AVAILABLE LIGHT COLLECTION REGION ON THE HOLOGRAPHIC SCANNING FACET, ASSIGNED THE SYMBOLIC NOTATION " r_{INNER} "

(16) ONE-HALF OF THE DEPTH OF FIELD OF THE (i, J)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION " δ "

(17) THE DISTANCE FROM THE MAXIMUM READ DISTANCE (f_i + 5") TO THE INNER RADIUS r_i OF THE SCANNING FACET, ASSIGNED THE SYMBOLIC NOTATION "C"

(18) THE OUTER RAY ANGLE MEASURED RELATIVE TO THE NORMAL TO THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION "α"

(19) THE INNER RAY ANGLE MEASURED RELATIVE TO THE NORMAL TO THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " γ "

(20) THE LIGHT COLLECTION ANGLE MEASURED FROM THE FOCAL POINT OR THE i-TH FACET TO THE LIGHT COLLECTION AREA OF THE SCANNING FACET, ASSIGNED THE SYMBOLIC NOTATION " β "

(21) THE INTERSECTION OF THE BEAM FOLDING MIRROR AND LINE C, ASSIGNED THE SYMBOLIC NOTATION " X "

(21A) THE INTERSECTION OF THE BEAM FOLDING MIRROR AND LINE C, ASSIGNED THE SYMBOLIC NOTATION " Y "

(22) THE DISTANCE MEASURED FROM THE INNER RADIUS TO THE POINT OF MIRROR INTERSECTION, ASSIGNED THE SYMBOLIC NOTATION " D "

(23) THE DISTANCE MEASURED FROM THE BASE OF THE SCANNER HOUSING TO THE TOP OF THE j-TH BEAM FOLDING MIRROR, ASSIGNED THE SYMBOLIC NOTATION " h "

(24) THE DISTANCE MEASURED FROM THE SCANNING DISC TO THE " d " BASE OF THE HOLOGRAPHIC, ASSIGNED THE SYMBOLIC NOTATION

(25) THE FOCAL LENGTH OF THE i-TH HOLOGRAPHIC SCANNING FACET FROM THE CORRESPONDING FOCAL PLANE WITHIN THE SCANNING VOLUME, ASSIGNED THE SYMBOLIC NOTATION " f_i "

(26) INCIDENT BEAM ANGLE, ASSIGNED THE SYMBOLIC NOTATION " A_i "

(27) DIFFRACTED BEAM ANGLE, ASSIGNED THE SYMBOLIC NOTATION "B_i"

FIG. 44B2

(28) THE ANGLE OF THE J-TH LASER BEAM MEASURED FROM THE VERTICAL, ASSIGNED THE SYMBOLIC NOTATION " $-\alpha$ "

(29) THE SCAN ANGLE OF THE LASER BEAM, ASSIGNED THE SYMBOLIC NOTATION "θ_{si}"

(30) THE SCAN MULTIPLICATION FACTOR FOR THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION "M_i "

(31) THE FACET ROTATION ANGLE FOR THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION " θ_{ROTi} "

(32) ADJUSTED FACET ROTATION ANGLE ACCOUNTING FOR DEADTIME, ASSIGNED THE SYMBOLIC NOTATION "θ'_{ROTi} "

(33) THE LIGHT COLLECTION EFFICIENCY FACTOR FOR THE i-TH HOLOGRAPHIC FACET, NORMALIZED RELATIVE TO THE 16TH FACET, ASSIGNED THE SYMBOLIC NOTATION " ξ_i"

(34) THE MAXIMUM LIGHT COLLECTION FOR THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION "$Area_i$ "

(35) THE BEAM SPEED AT THE CENTER OF THE (i, j)-TH SCANLINE, ASSIGNED THE SYMBOLIC NOTATION "V_{CENTER}"

(36) THE ANGLE OF SKEW OF THE DIFFRACTED LASER BEAM AT THE CENTER OF THE i-TH HOLOGRAPHIC FACET, ASSIGNED THE SYMBOLIC NOTATION "Φ_{SKEW}"

(37) THE MAXIMUM BEAM SPEED OF ALL LASER BEAMS PRODUCED BY THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "V_{MAX} "

(38) THE MINIMUM BEAM SPEED OF ALL LASER BEAMS PRODUCED BY THE HOLOGRAPHIC SCANNING DISC, ASSIGNED THE SYMBOLIC NOTATION "V_{MIN}"

(39) THE RATIO OF THE MAXIMUM BEAM SPEED TO THE MINIMUM BEAM SPEED, ASSIGNED THE SYMBOLIC NOTATION "V_{MAX} / V_{MIN} "

(40) THE DEVIATION OF THE LIGHT RAYS REFLECTED OFF THE PARABOLIC LIGHT REFLECTING MIRROR BENEATH THE SCANNING DISC, FROM THE BRAGG ANGLE FOR THE FACET, ASSIGNED THE SYMBOLIC NOTATION "δ_e"

FIG. 44B3

PARAMETER EQUATION USED IN THE SPREADSHEET
DESIGN OF THE SCANNER

(1) $\Delta x \quad := L\,(1 + \cos(2\Phi))$

(2) $\Delta y \quad := L \sin(2\Phi)$

(3) $\Delta y \quad := r_0 + \Delta x$

(4) $C \quad := \sqrt{(f+\delta)^2 + l^2 + 2\,(f+\delta)\,l\cos(B)}$

LAW OF COSINES, WHERE : $l = r_{outter} - r_{inner}$

$\beta = \alpha - \gamma = B + 2\Phi - 90 - \gamma$

(5) $\alpha \quad := B - 90 + 2\Phi$

(6) $r \quad := \alpha - \cos\left[\dfrac{(f+\delta)^2 + C^2 - l^2}{2\,(f+\delta)\,C}\right]$

(7) $\beta \quad := \alpha - \gamma$

(8) $X \quad := D\cos(B - \beta) + r_i$

(9) $Y \quad := D\sin(B - \beta)$

(10) $D \quad := \dfrac{[r_0 + L - r_i]\sin(90 + \ \ )}{\sin(90 - B + \beta - \Phi)}$ LAW OF SINES

(11) $h \quad := Y + d$

FIG. 44C1

$$(12) \quad f_i := \sqrt{a_i^2 + \left[m\, S_{SL} - \left[r_0 + \Delta x\right]\right]^2}$$

m IS A FACTOR THAT VARIES FROM SCAN LINE TO SCAN LINE AND DETERMINED BY SCAN LINE SEPARATION AND DISTANCE FROM THE ROTATIONAL AXIS OF THE DISC.

$$(13) \quad B_i := \operatorname{atan}\left[\left[\frac{m\, S_{SL} - \left[r_0 + \Delta x\right]}{a_i}\right]\right] + 90 - 2\Phi$$

$$(14) \quad \Phi_{Si} := 2 \operatorname{atan}\left[\left[\frac{\frac{1}{2}\ \text{ScanLineLength}}{f_i}\right]\right]$$

$$(15) \quad M_i := \frac{r_0}{f_i} + \cos(\lambda_1) + \cos(B_i)$$

$$(16) \quad \Theta_{roti} := \frac{\Theta_{Si}}{M_i}$$

$$(17) \quad \Theta'_{roti} := \Theta_{roti} + \underbrace{\frac{d_{beam}}{r_o} + \frac{d_{gap}}{r_o}}_{\Theta_{dead}}$$

$$(18) \quad \xi_i := \left[\frac{f_i}{f_{16}}\right]^2 \frac{\sin\left[B_{16}\right]}{\sin(B_i)} \quad H_i$$

$$(19) \quad \text{Area}_i := \pi\left[r_{outter}^2 + r_{inner}^2\right] \quad \frac{\xi_i}{\sum_{i=1}^{16}\left[\xi_i\right]} \qquad i = 1,2,\ldots 16$$

FIG. 44C2

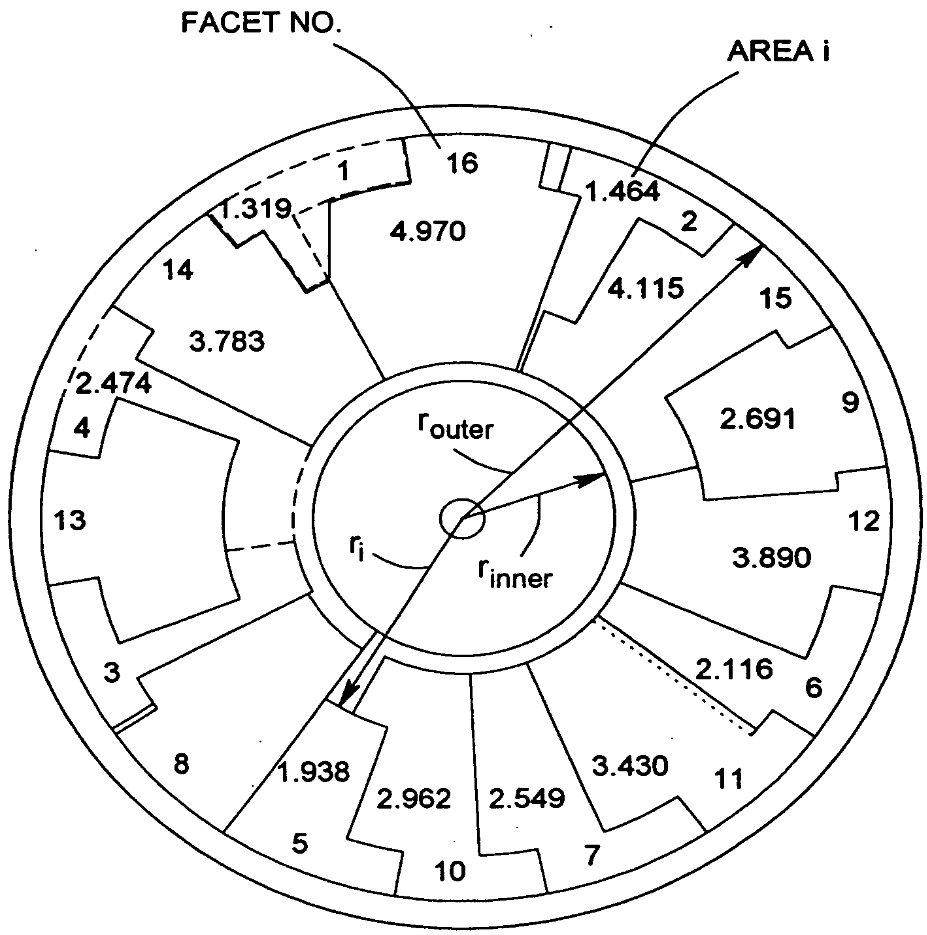

FACET NO.
AREA i
16
1
1.319
4.970
1.464
2
4.115
15
14
3.783
2.474
4
9
2.691
r_{outer}
13
12
r_i
r_{inner}
3.890
3
2.116
6
8
1.938
2.962
2.549
3.430
11
5
10
7

FIG. 44D

VECTOR MODELING OF LASER SCAN BEAMS IN HOLOGRAPHIC SCANNING SUBSYSTEMS

MATHEMATICAL FORM FOR EACH LASER SCAN BEAM:
VECTOR-BASED MODEL OF OPTICAL PATH OF BEAM FROM DISC TO MIRROR TO FOCAL PLANE (∞)

PROCEDURE:

(1) USE POSITION VECTOR REFERENCED FROM X=0, Y=0, Z=O IN $R_{\text{local scanner}}$, FOR SPECIFYIED THE STARTING POINT OF LASER SCAN BEAM ON DISC, AND DIRECTION VECTOR FOR SPECIFYING THE DIRECTION OF LASER BEAM THE BEAM FOLDING MIRROR; AND
(2) USE POSITION VECTOR FOR SPECIFYING POINT ON MIRROR WHERE BEAM IS REFLECTED FROM BEAM FOLDING MIRROR TOWARDS FOCAL PLANE OF FACET, EXTENDING TO INFINITY, AND DIRECTION VECTOR FOR SPECIFYING THE DIRECTION OF LASER BEAM TOWARDS DESIGNATED FOCAL PLANE

(3) THESE FOUR VECTORS SPECIFY THE LASER BEAM RAY IN LOCAL COORDINATE REFERENCE $R_{\text{local scanner}}$

FIG. 45

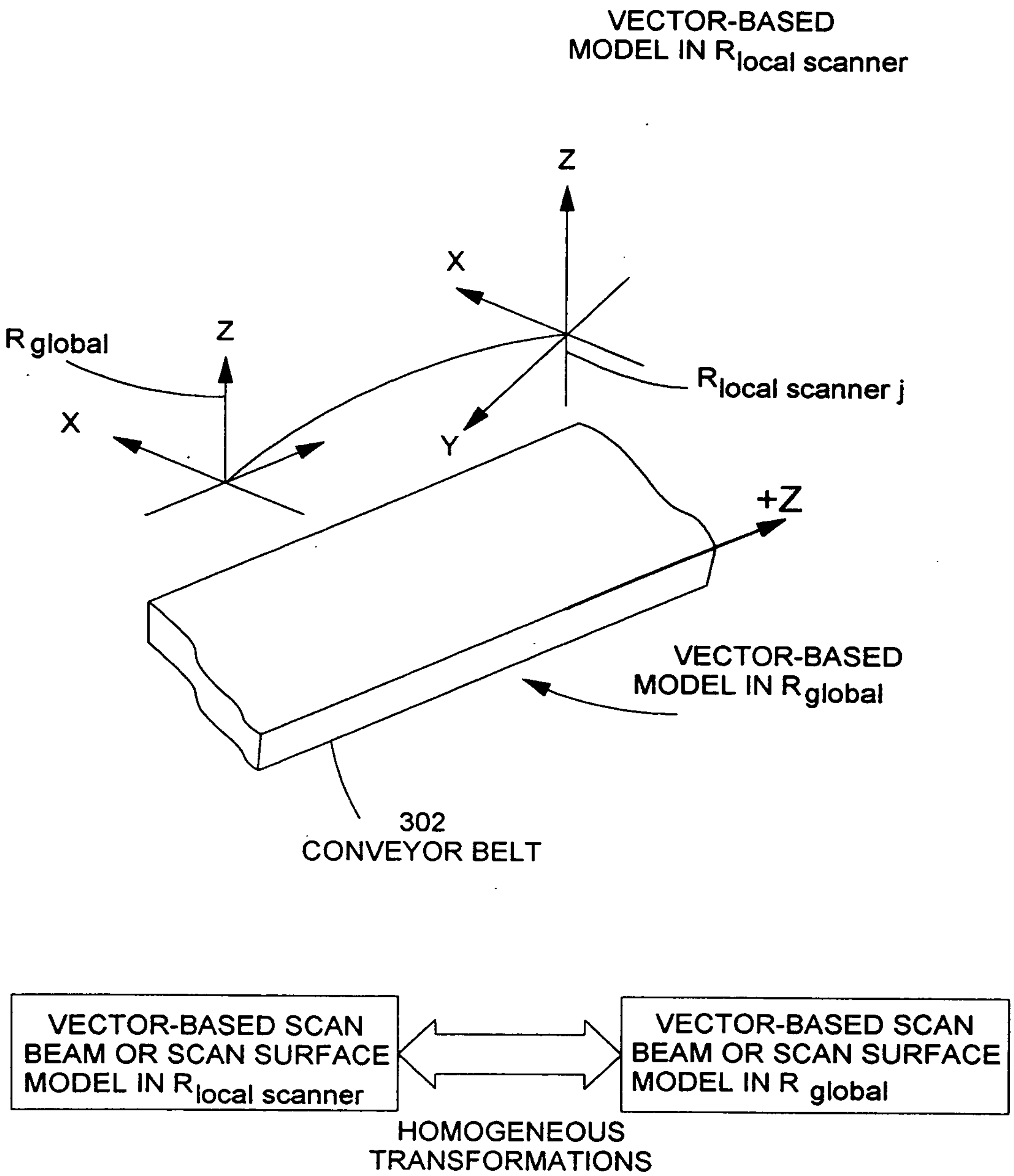
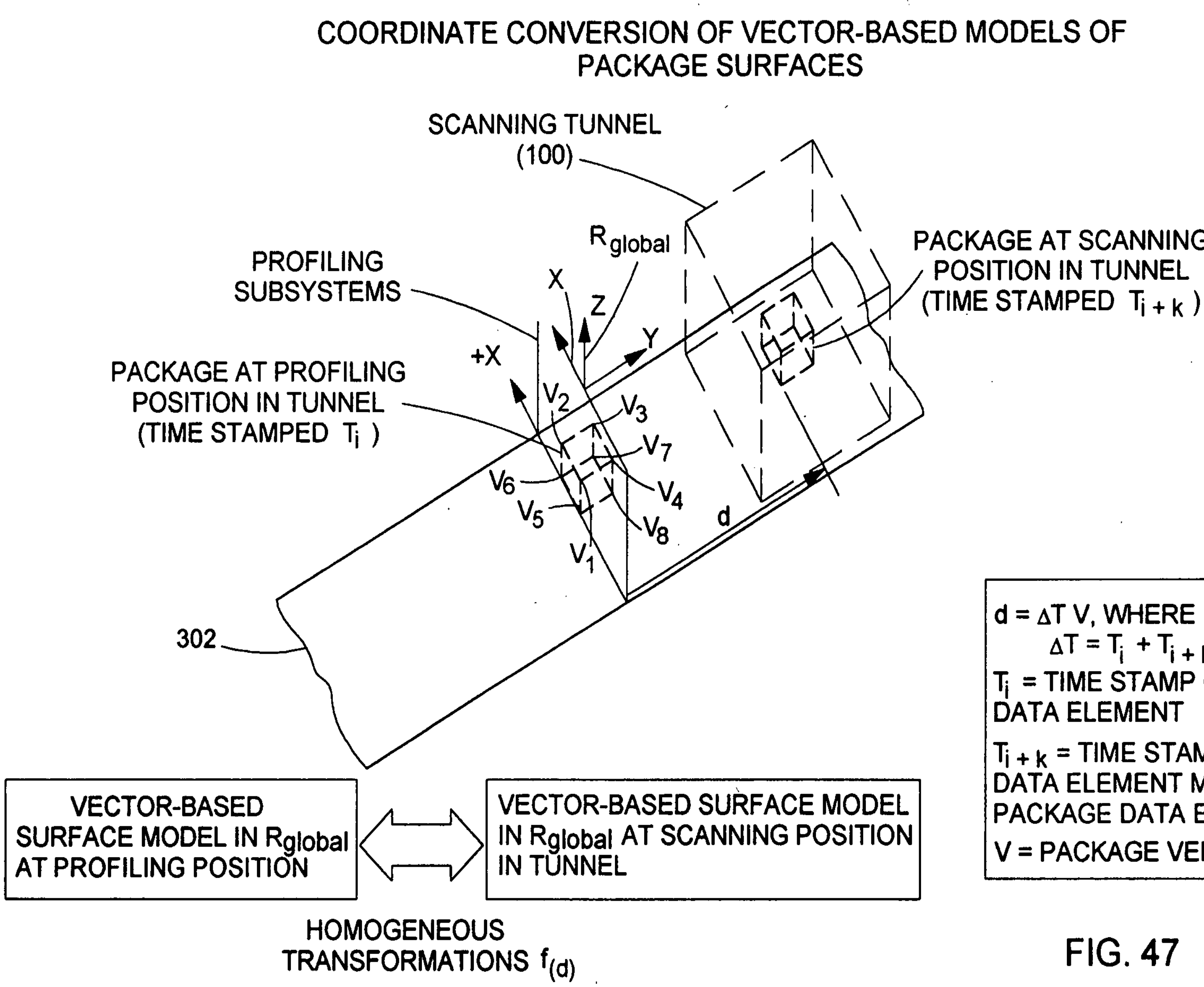

VECTOR-BASED
MODEL IN R local scanner
Z
X
R global
Z
X
R local scanner j
Y
+Z
VECTOR-BASED
MODEL IN R global
302
CONVEYOR BELT
VECTOR-BASED SCAN BEAM OR SCAN SURFACE MODEL IN R local scanner
VECTOR-BASED SCAN BEAM OR SCAN SURFACE MODEL IN R global
HOMOGENEOUS TRANSFORMATIONS

FIG. 46



$d = \Delta T\, V$, WHERE
$\Delta T = T_i + T_{i+k}$
T_i = TIME STAMP ON PACKAGE DATA ELEMENT
T_{i+k} = TIME STAMP ON SCAN DATA ELEMENT MATCHED TO PACKAGE DATA ELEMENT
V = PACKAGE VELOCITY

FIG. 47

SCAN BEAM/PACKAGE SURFACE INTERSECTION DETERMINATION METHOD FOR SCAN DATA ELEMENTS PRODUCED FROM HOLOGRAPHIC SCANNING SUBSYSTEMS

A

USING THE MINIMUM AND MAXIMUM SCANNING MODELS OF THE LASER SCAN BEAM, DETERMINE THE INTERSECTION POINT BETWEEN THE SCAN RAY AND A SURFACE ON THE PACKAGE (USING THE VECTOR-BASED MODELS THEREOF), REFERENCED TO THE GLOBAL COORDINATE FRAME R_{global}

↓

B

IF AN INTERSECTION POINT IS DETERMINED, THEN CONFIRM THAT SIGN OF THE NORMAL VECTOR OF THE SURFACE IS OPPOSITE THE SIGN OF SCAN RAY DIRECTION VECTOR

↓

C

IF SIGN OF NORMAL VECTOR IS OPPOSITE SIGN OF SCAN RAY DIRECTION VECTOR, THEN DETERMINE IF INTERSECTION POINT (FOUND IN STEP ABOVE) FALLS WITH SPATIAL BOUNDARIES OF THE PACKAGE SURFACE

↓

A

FIG. 48A

A

D

IF INTERSECTION POINT FALLS WITHIN BOUNDRIES OF SURFACE, THEN OUTPUT OF A DATA ELEMENT IN OUTPUT QUEUE COMPRISING THE PACKAGE I.D. DATA AND THE DIMENSIONS AND MEASUREMENTS (e.g. L, H, W AND WEIGHT) OF PACKAGE FOR USE BY OTHER SUBSYSTEMS

FIG. 48B

1-D CCD SCANNER EMBODIMENT

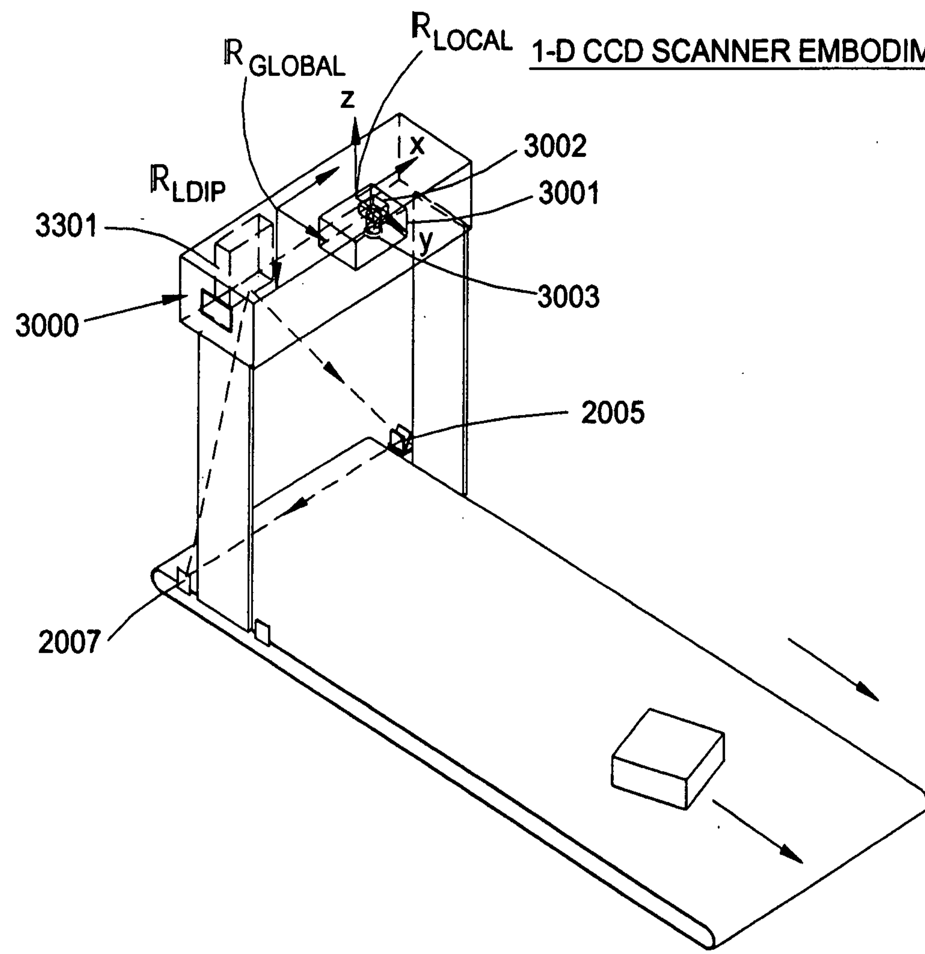


FIG. 49

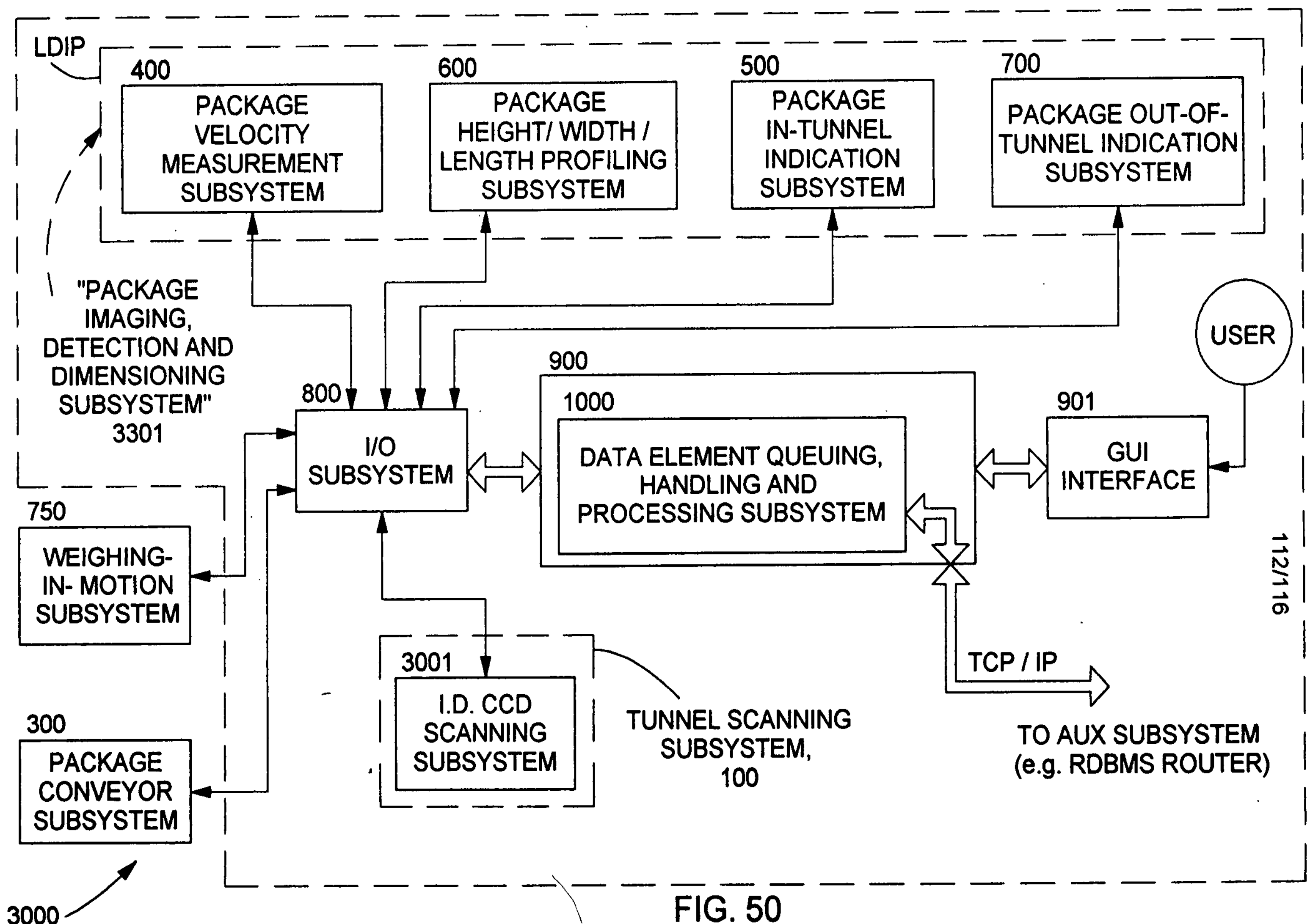
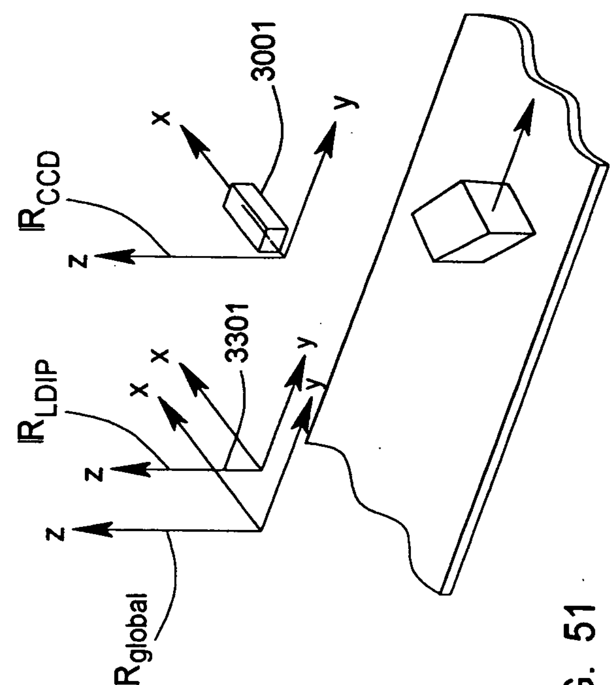
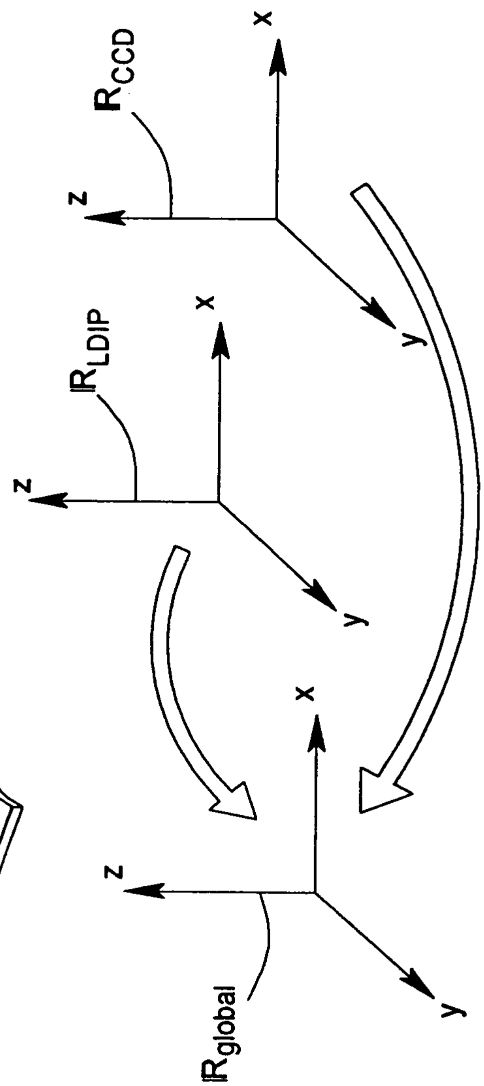

LDIP
400
PACKAGE VELOCITY MEASUREMENT SUBSYSTEM
600
PACKAGE HEIGHT/ WIDTH / LENGTH PROFILING SUBSYSTEM
500
PACKAGE IN-TUNNEL INDICATION SUBSYSTEM
700
PACKAGE OUT-OF-TUNNEL INDICATION SUBSYSTEM
"PACKAGE IMAGING, DETECTION AND DIMENSIONING SUBSYSTEM" 3301
USER
800
I/O SUBSYSTEM
900
1000
DATA ELEMENT QUEUING, HANDLING AND PROCESSING SUBSYSTEM
901
GUI INTERFACE
750
WEIGHING-IN- MOTION SUBSYSTEM
3001
I.D. CCD SCANNING SUBSYSTEM
TUNNEL SCANNING SUBSYSTEM, 100
TCP / IP
TO AUX SUBSYSTEM (e.g. RDBMS ROUTER)
300
PACKAGE CONVEYOR SUBSYSTEM
3000

FIG. 50



$\mathbb{R}_{CCD}$
z
x
y
3001
$\mathbb{R}_{LDIP}$
z
x
x
y
y
3301
z
$\mathbb{R}_{global}$

FIG. 51



R_{CCD}
z
x
y
$\mathbb{R}_{LDIP}$
z
x
y
z
x
y
$\mathbb{R}_{global}$

FIG. 52

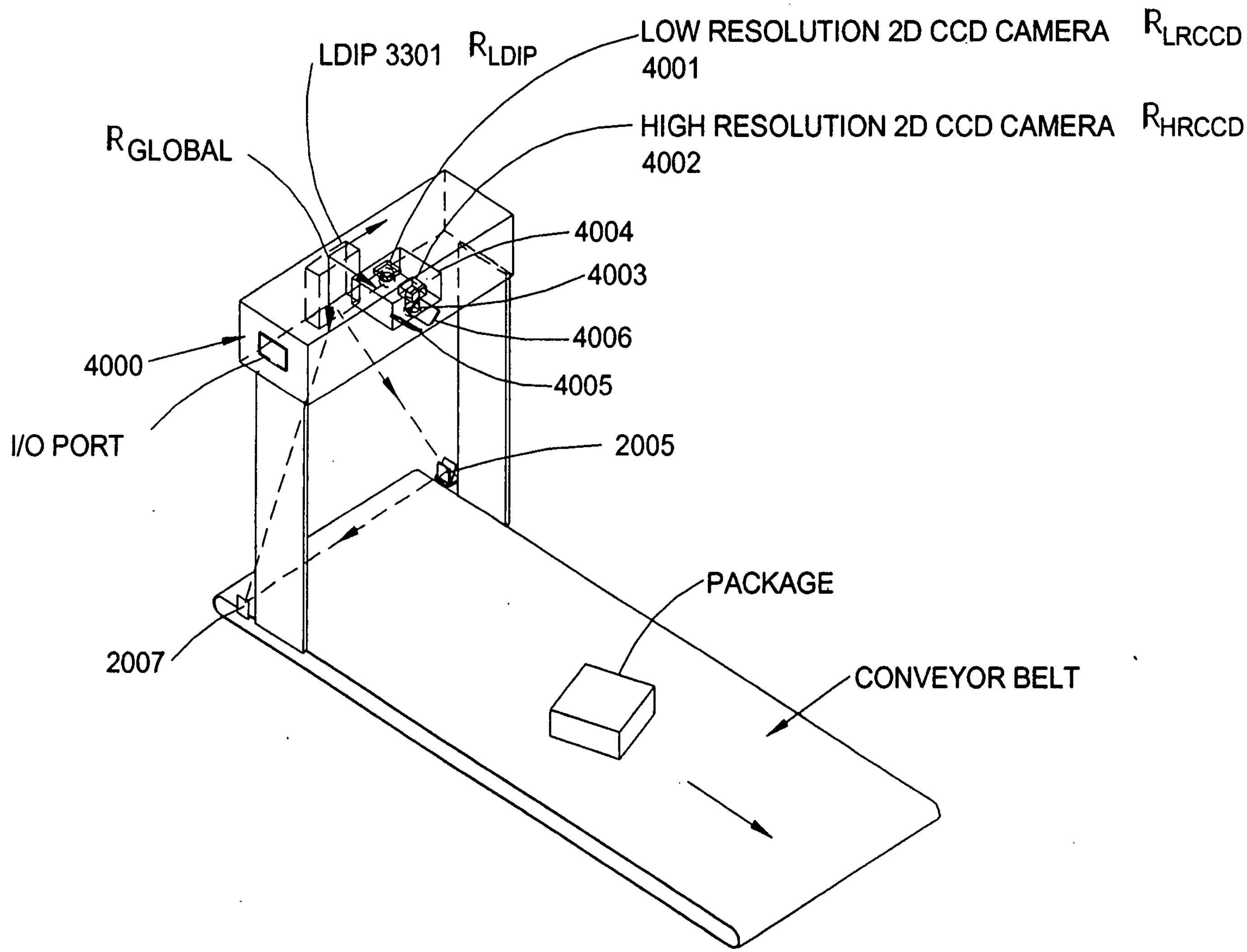

LDIP 3301
R_{LDIP}
LOW RESOLUTION 2D CCD CAMERA
4001
R_{LRCCD}
HIGH RESOLUTION 2D CCD CAMERA
4002
R_{HRCCD}
R_{GLOBAL}
4004
4003
4006
4005
4000
I/O PORT
2005
PACKAGE
2007
CONVEYOR BELT

FIG. 53

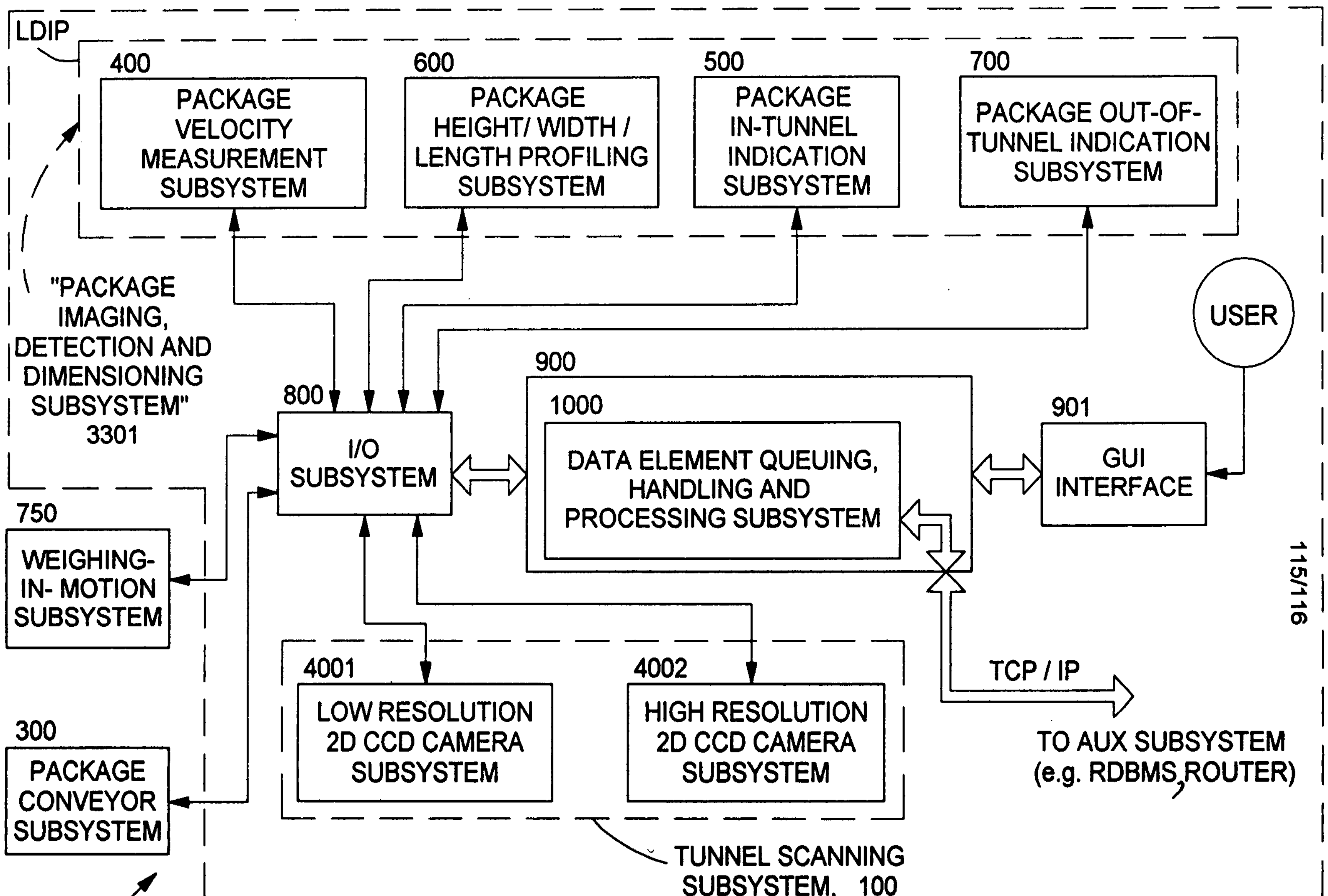
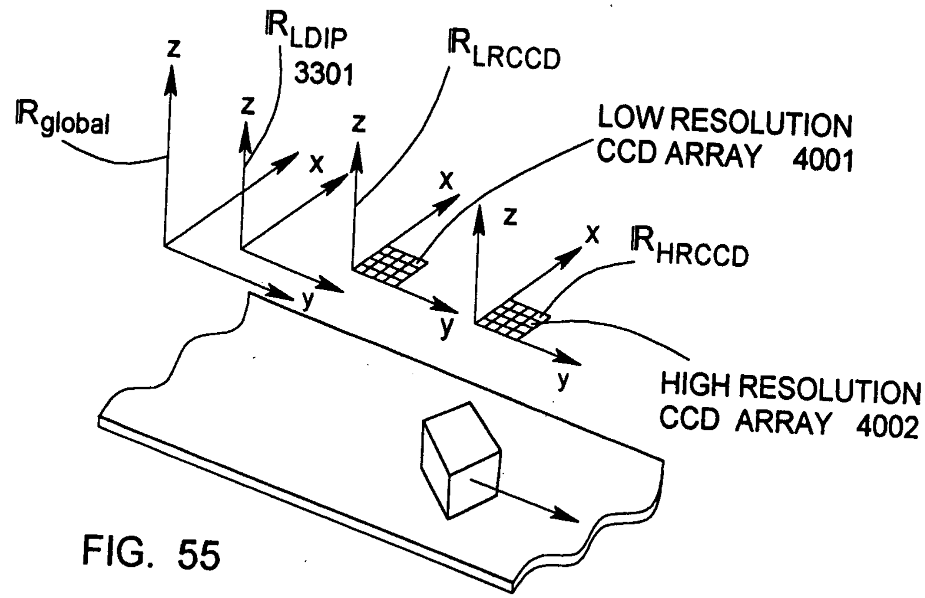
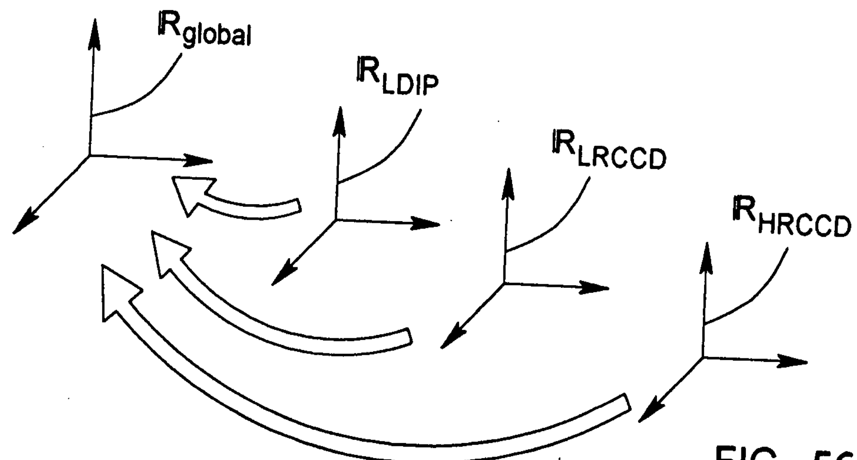

LDIP
400
PACKAGE VELOCITY MEASUREMENT SUBSYSTEM
600
PACKAGE HEIGHT/ WIDTH / LENGTH PROFILING SUBSYSTEM
500
PACKAGE IN-TUNNEL INDICATION SUBSYSTEM
700
PACKAGE OUT-OF-TUNNEL INDICATION SUBSYSTEM
"PACKAGE IMAGING, DETECTION AND DIMENSIONING SUBSYSTEM" 3301
800
I/O SUBSYSTEM
900
1000
DATA ELEMENT QUEUING, HANDLING AND PROCESSING SUBSYSTEM
901
GUI INTERFACE
USER
750
WEIGHING-IN- MOTION SUBSYSTEM
300
PACKAGE CONVEYOR SUBSYSTEM
4001
LOW RESOLUTION 2D CCD CAMERA SUBSYSTEM
4002
HIGH RESOLUTION 2D CCD CAMERA SUBSYSTEM
TCP / IP
TO AUX SUBSYSTEM (e.g. RDBMS, ROUTER)
TUNNEL SCANNING SUBSYSTEM, 100
4000

FIG. 54



$\mathbb{R}_{global}$
$\mathbb{R}_{LDIP}$ 3301
$\mathbb{R}_{LRCCD}$
LOW RESOLUTION CCD ARRAY 4001
$\mathbb{R}_{HRCCD}$
HIGH RESOLUTION CCD ARRAY 4002
z
x
y

FIG. 55



$\mathbb{R}_{global}$
$\mathbb{R}_{LDIP}$
$\mathbb{R}_{LRCCD}$
$\mathbb{R}_{HRCCD}$

FIG. 56